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Working environments in NewSpace product development – A case study of a nanosatellite startup

Master's thesis submitted in partial fulfilment of the requirements for the degree of Master in Science in Technology

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Abstract

Workspaces, along with work culture, are constantly evolving. The ongoing trend of creating inviting working environments and increasing productivity by fulfilling individual needs is reaching to all the fields, including the most conventional ones, such as space industry. During the past few decades, this traditionally inflexible and conservative industry has seen an emerging transition towards agile and market-driven direction. In the professional world, this growing phenomenon of commercialisation and privatization of space technology is referred as NewSpace.

The purpose of this study was to determine what kind of working environment supports NewSpace. To get there, differences between conventional space industry and NewSpace were highlighted, serving as a basis of needs for entrepreneurial space activities. Additionally, the concept of working environment was analysed to determine the attributes which create a desirable basis for working. These needs and desirables provided a framework of working environment design for a NewSpace company.

The study starts with a comprehensive literature review and proceeds to practical part, consisting of observations, interviews and a practical re-arrangement setup for the case company, Reaktor Space Lab (RSL), a new-found startup that spun off from a university project. Emphasis was put to measurability and its difficulties, therefore an online survey was conducted and the results were analysed. The goal of the survey was not only to evaluate the current state of RSL, but to assess the importance of comprehensive working environment design and evaluate its relevance to NewSpace industry.

The study produced findings that can be summarized into following statements: 1) In space industry, modern and comprehensive design of working environment is only seldom taken into consideration and it is often seen as a cost rather than necessity, 2) workspace as such does not provide an extensive solution for environmental change, therefore emphasis should be put into understanding case-specific needs and approaching organisational change on a systematic level and 3) Working environment design does have impact to NewSpace companies, however the approach applies only to certain sort of space projects, so it shouldn't be taken as a platitude in space industry.

Based on these findings, this thesis provides fundamental suggestions for space technology companies that aim to develop its procedures towards agile NewSpace methodology. In addition, practical improvement proposals for RSL are proposed.

Keywords NewSpace, product development, space technology, working environment, workspace, startup

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Tiivistelmä

Työpaikat ja työkulttuuri kehittyvät jatkuvasti. Kutsuvien, käyttäjien tarpeita mukailevien työympäristöjen luominen on yleistynyt alaan katsomatta – myös perinteisemmillä aloilla, kuten avaruusteollisuudessa. Tämä verrattain jäykkä ja täsmällinen teollisuudenhaara on kohdannut uuden ilmiön, jossa yksityiset avaruustoimijat yhdistävät ketterät toimintatavat ja markkinalähtöisyyden. Tästä yrittäjähenkisestä lähestymistavasta käytetään nimitystä NewSpace.

Tämän diplomityön tarkoituksena oli selvittää, minkälainen työympäristö tukee NewSpace-toimintaa. Tämän määrittelemiseksi selvitettiin perinteisen avaruusteollisuuden ja NewSpace-tavan eroja, minkä perusteella määriteltiin kaupallisen avaruustoiminnan tarpeet. Lisäksi määritettiin työntekoa tukevan ympäristön ominaisuuksia tutkimalla modernia työympäristöä konseptitasolla. Näiden tarpeiden ja toivottujen ominaisuuksien avulla luotiin puitteet NewSpace-työympäristölle.

Tutkimus alkaa kirjallisuuskatsauksella, joka luo pohjan käytännön osiolle. Tutkimusmetodeina käytetään kirjallisuuskatsauksen lisäksi havainnointia, haastatteluita sekä käytännön uudelleenjärjestelyjä kohdeyrityksessä Reaktor Space Lab. Tämän yliopistoprojektista liikkeelle lähteneen pienyrityksen työympäristöä ja sen muutoksia mitataan online-kyselyllä, jonka avulla saatiin tuloksia ja johtopäätöksiä sekä kohdeyrityksestä, että avaruusyrittäjyydestä yleisellä tasolla.

Tutkimustuloksista tehtiin yhteenvetoja, jotka voidaan tiivistää seuraavasti: 1) Avaruusalalla otetaan harvoin huomioon työympäristö kattavasti siten, että se tukee henkilöstön tarpeita ja organisaation yhteisiä tavoitteita. 2) Työtilat eivät sellaisenaan tue ympäristön muutosta, joten muutoksessa tulee ottaa huomioon tapauskohtaiset organisaation ja yksilöiden tarpeet sekä toiminnan tavoitteet. 3) Kattavalla työympäristösuunnittelulla on vaikutusta NewSpace-toimintaan, mutta NewSpace ei sellaisenaan sovellu kaikkeen avaruustoimintaan.

Tuloksien perusteella laadittiin ehdotus yleisistä toimintatavoista, jonka avulla voidaan kehittää työympäristö tukemaan ketterää NewSpace-avaruustoimintaa. Lisäksi tuotiin esille ehdotuksia kohdeyrityksen työympäristön kehittämiselle.

Avainsanat NewSpace, avaruusteknologia, työympäristö, työtilat, tuotekehitys

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Space seems to bring people together indeed. Our ongoing project Space on Fire has an incredible nature of connecting curious minds – without this wonderful group of people, the field trips to CERN and SpaceX would have not happened. I am very much looking forward for our forthcoming journeys towards the unknown.

Last and most importantly, I would like to express how grateful I am for my family, who has shown constant support and understanding, regardless of my lifestyle – which tends to get hectic from time-to-time. I am truly blessed to have such caring parents and sister.

29th of May 2017, Helsinki

Jami Sarnikorpi

Table of Contents

Commonly Used Terms and Abbreviations

BIC	Business Incubator Centre (ESA)
CERN	European Organization for Nuclear Research *(Conseil Européen pour la Recherche Nucléaire)*
CNES	National Centre for Space Studies (*Centre National d'Etudes Spatiales*), French government space agency
COTS	Commercial off-the-Shelf
ESA	European Space Agency
GEO	Geostationary Orbit
GPS	Global Positioning System
ISS	International Space Station
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
NewSpace	Term used for global industry of private companies and entrepreneurs developing products or services in the field of space technology
RSL	Reaktor Space Lab
R&D	Research and Development
SAE	Society of Automotive Engineers
SME	Small and Medium-sized Enterprise(s)
SpaceX	Space Exploration Technologies Corporation
SSI	Space Systems Inc.
S&P 500	Standard & Poor's 500 index
UNOOSA	The United Nations Office for Outer Space Affairs
VTT	Technical Research Centre of Finland (*Valtion Tieteellinen Tukimuskeskus*)

1 Introduction

1.1 Background

Space technology has presented remarkable scientific and technological breakthroughs during the last six decades. It has literally travelled a long way since the first successful liquid-fueled rocket launch in 1926 – the furthest travelled probe, Voyager 1, is already traveling way beyond the outer skirts of our solar system. However, space industry and its methods in general have not changed much during the past five decades it has existed. As during the space race, in the times of Cold War, space agencies are still planning long, publicly funded missions that aim for strong predictability by putting emphasis on careful preplanning and reliability.

To challenge the given structures and methods of space industry, a small commercial sector has been rapidly growing during the past few decades. This shift of commercialisation and privatization of space industry, also known as NewSpace, is constantly looking for new fields of operation and new ways of achieving its goals. For example, after the termination of Space Shuttle, the famous American transportation to Earth's orbit and back, multiple private companies have changed the way space is accessed. Nevertheless, the change does not necessarily have to be big in terms of physical dimensions – nanosatellites, the modern icons of entrepreneurial space activity, are changing the way space projects are seen.

The challenge with the current situation is, that conventional space industry and national space agencies lack ways of approaching and supporting entrepreneurial space industry. In other words, their working environments do not support agile NewSpace methodology. Therefore, it is necessary to understand what kind of working environments support NewSpace and how these environments can be created.

1.2 Research questions and scope

The objective of this study is to determine what kind of working environment supports NewSpace activities. To do so, firstly it is essential to understand what kind of needs does the modern commercial space industry have. To determine the needs, differences between conventional space industry and NewSpace are highlighted.

Secondly, as working environment is a broad term, it should be defined in the context of this study. Being the sum of its parts, it is also relevant to determine what working environment consists of and what are the matters that affects it. These basic questions lead to determination of working environment attributes, that support the modern needs of industry.

Using the needs of NewSpace industry and desired attributes of a modern working environment, main scope of the study can be framed by following research questions:

1. **What kind of working environment supports activities related to NewSpace?**

2. **How could a suitable working environment be implemented?**

These two questions lead into further practical questions, like how can the current state of a working environment be determined and what are the indicators of progress during the development.

This study focuses in working environments in the field of NewSpace. However, due lack of literature in the field and limitations related to the case study, it was reflected in a wider context. Therefore, the scope of this study covers working environments in high-tech industries, including – but not limited to – space technology.

1.3 Methods

The main method for measured outcomes of this study is an online survey, which is based on conclusions of the literature review. Furthermore, the case company was studied utilizing observations, discussion and pilot testing. Semi-conducted interviews were used for background research in external companies and institutions.

1.4 Structure of the thesis

This study is divided into seven different sections, shown in **Figure 1**. The first one introduces the topic and structure. The second section first defines space industry and its historical characteristics, and then distinguishes NewSpace methodology from traditional space industry. These differences are highlighted in a summary. The third section proceeds by taking a theoretical approach for change mechanism of organisations and values, and then reflects these to the shift of working environments. Furthermore, working environments are taken into consideration from NewSpace point-of-view, using field trips and interviews as means to understand the situation better.

The learnings from second and third sections are taken into consideration in the fourth section, that investigates the case company, Reaktor Space Lab (RSL), by observing and practical testing. The current situation of RSL, along with the impact of development during the period of study, are measured in the fifth section using a survey. Sixth chapter provides the key findings of the case study and literature, together with discussion and suggestions. Seventh chapter concludes the main content and learnings.

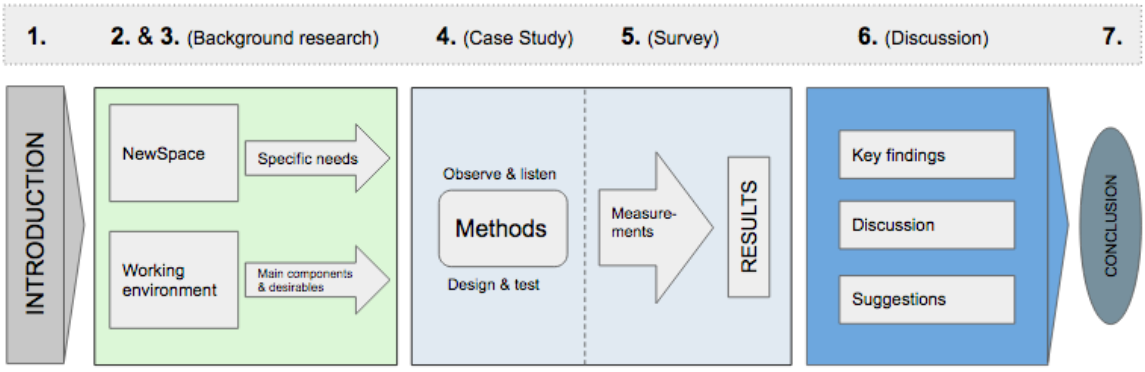

Figure 1 Structure of the thesis

2 Space industry and its ongoing shift

2.1 Space technology as an enabler of space industry

To understand the shift in space industry, it is necessary to understand where it's coming from and how it differentiates from other industry. The term *space technology* refers to technical inventions related to astronautics, the science of the construction and operation of vehicles for travel beyond the Earth's atmosphere. [1] *Space industry*, on the other hand, covers the economic activities relateted space technology. As Blomberg (2000) puts it in her book: "Space industry consists of a group of large and small private firms that produce, as at least part of their output, launchers, satellites, rocket engines, and other kinds of space hardware and services." [2]

Although space technology emerged mostly by the efforts of public sector, like institutions and universities, the private and the public have been closely associated from the begin. National Aeronautics and Space Administrator (NASA), one of the very first space agencies ever which at present covers around half of all space agency budgets worldwide, had multiple leaders of aerospace industry on the board of advisors during its establishment in 1958. However, as the industry was long funded by public sector, the market-driven commercialisation, meaning getting revenue from private sector began in the 1990's. [2][3]

The total size of space economy in 2015 was 320 billion US dollars. **Figure 2** shows how the main sectors are divided between governmental budgets and commercial revenues: around a quarter of all space acitivites goes to public space programs, including scientific missions, national telecommunications and national space-related defence operations, for example. The commercial part, clear dominat of the global space activities is divided into two almost equal

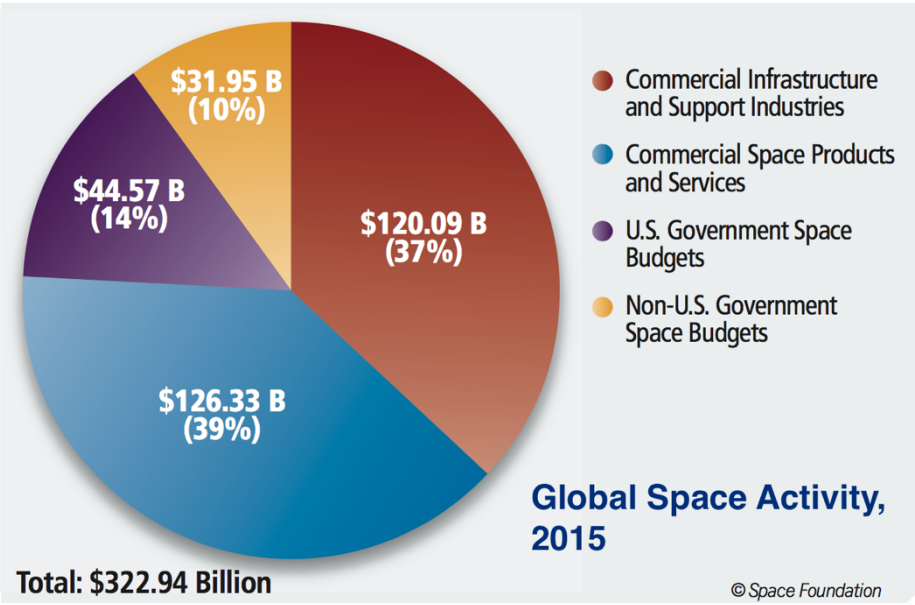

Figure 2 Global space activity in US dollars in 2015 [3]

sectors, out of which the slightly larger one covers space products, leaving the rest for infrastructure and support industries. [3]

Generally speaking, each one of space market segments are driven by notably larger associated world-wide market segmets. For instance, satellite industry, the largest sector of space industry (total share of 61% in 2013), is equivalent to about 4% of overall 5 trillion (USD) telecommunications industry. [4] The other bigger mature categories, like national security as well as research and development (R&D), are also taking similar shares of the main sectors, especially in US, that is currently the biggest market in space economy. **Figure 3** shows how the revenues of commercial space between three general sections of manufacturing, satellite operators and consumer services in 2013. In this division, most of the satellite industry is categorized as consumer services. [5]

Regardless of the drops in global economy growth during the past decade, space industry has been growing steadily. Even during the financial crisis in 2008, after which many industries contracted, global space economy kept its growth on the positive side, being 5% in 2014-2015. In the past decade, space industry has outperformed the global economy every year except 2010.[4][5] A notable change in the fifty-year-old industry has been investments in small and medium sized entreprises, or commonly known as space-related startups. In 2015, these newcomers in the field collected 2,7 billion US dollars in financing, out of which 2,3 billion was investment. While still representing only a small fraction of the global space industry, space startups showed a remarkable compound annual growth rate of 180 percet during 2012–2015. [6]

There are various trends affecting the space economy, most of them in a positive way. For example, it is estimated, that access to space is getting more diverse and cost-efficient already within the next five years. [1] There's multiple driving forces behind this, strongest being the constantly growing demand, as there's a growing number of companies and institutions producing spacecrafts.

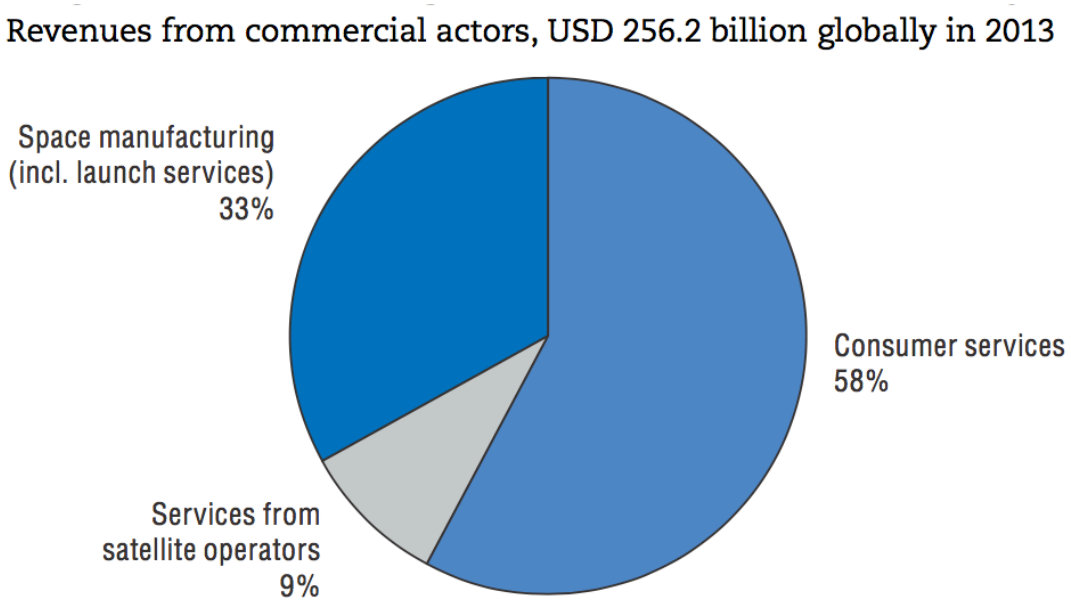

Figure 3 Market share of commercial space industry in 2013, divided into general categories [5]

Simultaneusly, the electronic components are getting cheaper, smaller and more reliable, which further increases the amount ongoing projects, like small satellites. [4] The growing demand for data gained from satellites is driving recent investments in various broad conventional industry sectors, like agriculture, surveillance and energy production. In general, the space institutions, that still have a critical role in starting-up and developing space sector, show no negative trends towards space development. Vice versa; a number of economies, like Germany, France and Japan have increased their outlays for space R&D. [5]

2.1.1 Three phases of space technology

MacDonald et al. divide the development of space technology into three main stages according to generic technology development, originally based on the diffusion of innovations theory (**Figure 4**). Although the diffusion of innovation curve is very simplified and does not necessarily represent modern networked technology adaption accurately, it can be adopted to space technology using commonly accepted milestones in following way [7]:

- Phase 1: Late 1800's – 1957 *(Early pioneering & theories)*
- Phase 2: 1957 – present *(Space age)*
- Phase 3: Present – *(Entrepreneurial space & manned flights beyond Earth's orbit)*

Phase 1

As the first effort to launch an object into Earth's orbit, the modern form of "Ideal Rocket Equation" was publicly introduced by Konstantin Tsiolkovsky in 1903 on

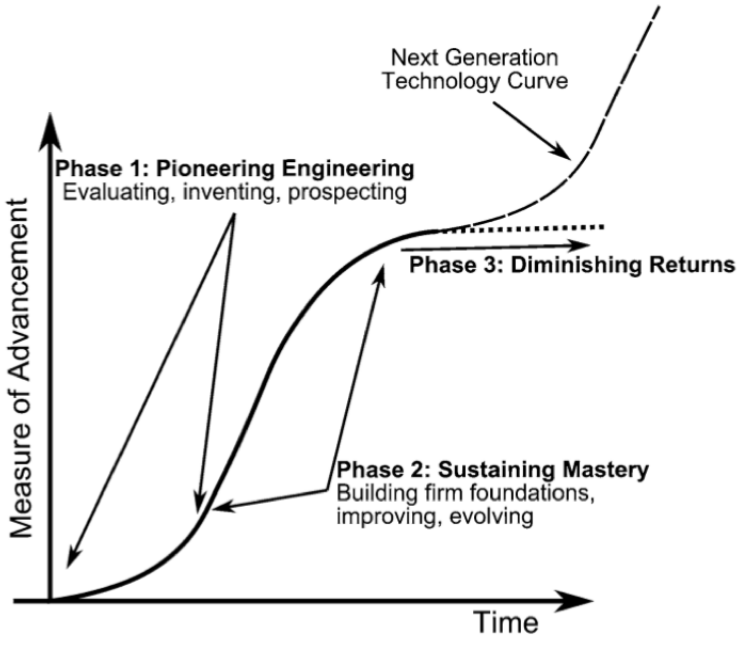

Figure 4 Three main phases of space technology fit into generic technology curve, cultivated from diffusion of innovations theory [2]

Russian Scientific Review: Investigation of Outer Space Rockets. [8] However, the first rocket equations were calculated even before that, approximately in late 1870's, so it is stated and commonly accepted, that the space technology was born in the late 1800's. The next leap was taken in 1926 as the first successful liquid-fueled rocket was launched by American Robert Goddard. There was still a long way for space technology to be taken seriously: at that time Goddard's breakthrough in rocket tests was widely ridiculed in New York Times. It took altogether forty-three years for the to issue a correction and apologize – one day after Apollo-11 was successfully launched to moon and brought back in 1969. [8]

Phase 2

The actual Space age is considered to begun in 1957 as Sputkik-1, the first earth-orbiting object was launched to space by the Soviet Union. Next year the satellite was followed by Explorer-1, the first American spacecraft, which has been seen as the beginning of the Space Race, a competition between two superpowers that eventually accelerated the whole space industry exponentially. [8]

The speed of the growing industry in the new era was magnificent. While in the 1980's there were still only very few countries that were able to launch satellites into orbit, already in 1990's the commercialisation of space industry took a big step as the Ariane 4 launch vehicle, developed by French CNES (National Centre for Space Studies) and a multinational company Arianespace, conquered over half of the commercial launch market. This enabled world-wide satellite TV to become popular, therefore bringing space industry closer to people's everyday lives. Another big leap took place in 1994, when GPS (Global Positioning System), developed and operated by US Department of Defence, became available for public use, therefore bringing space applications closer to everyday life. [5][8]

From the 1990's till now, the space sector has been growing steadily. Countless innovations and technical developments have enabled multiple scientific breakthroughs, both on Earth's orbit and deep space exploration. On the one hand, Earth observation has taught us more about the current state and especially the changes of our planet than any other conventional ground-level scientific methods. The best single example of these research objects is climate change, as the long-term monitoring has generated the widest and most accurate proof on global impact of human activity especially during the past three decades. [9] Also, our understanding of the universe is growing exponentially as both on-ground monitoring and deep space missions produce constant data. Simultaneously, the sensors are getting more precise, data transfer bandwidth capability is getting higher and the capacity to process data is increasing. [10]

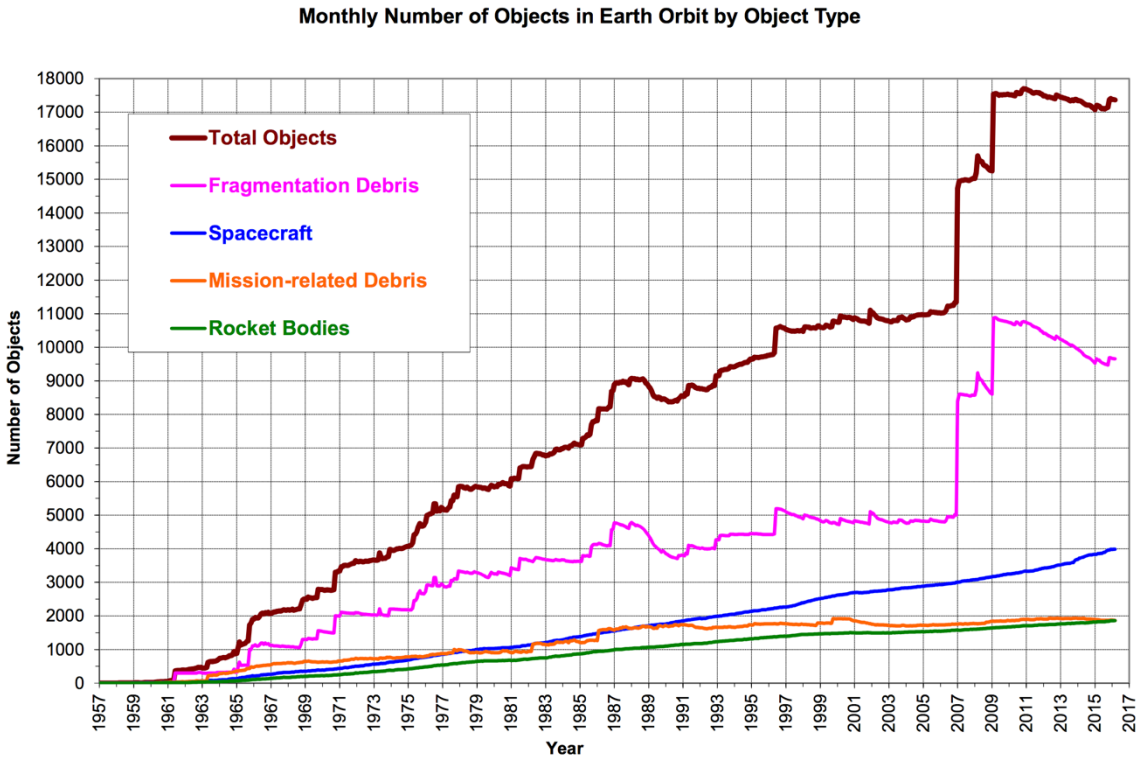

Figure 5 Monthly number of objects in Earth orbit by object type. The rapid rice in fragment debris, including satellite breakup debris, can be explained with China's anti-satellite test in 2007 and a collision of deactivated Soviet satellite and US satellite on its mission in 2009 (NASA 2016) [11]

Phase 3

Currently, we are living in the shift between phase 2 and phase 3. **Figure 5** shows the constant, yet steady growth of objects on our Earth's orbit. The number is expected to grow rapidly in the next two decades, as companies like Google and SpaceX are planning and testing multi-hundred and even multi-thousand Low Earth Orbit (LEO) satellite constellations. [11] Another trend to accelerate space technology is human spaceflights beyond Earth's orbit; NASA and other institutions and companies are placing major investments in launching manned spacecrafts to Mars, which is generally considered as the next moonshot and the beginning of new space era. [12]

Another trend shaping the future of space is the constantly growing commercial sector. This growth is expected to touch industries beyond traditional space-related fields, like agriculture and mobile platforms. A good example of these kind of platforms is Google Maps, a GPS-based map application that provides a pre-made interface and access to data for developers. The application is free for users and developers and it gets the revenue from advertisement. While Google keeps its numbers as a secret, it published in 2014 that Google Maps has over one billion users, who in other words benefit directly from a space-based service. [13][14]

2.2 Conventional space industry approach

In the context of this study, conventional space industry refers to the traditional methodology of producing space technology. The early space missions in the 1950's started as ambitious and risky projects, that were backed up by governmental space programs. [8]

Due the complex, yet often revolutionary nature of the missions, project development cycles were long and heavy. The missions were unique and extremely resource-consuming, therefore the risks of failure had to be minimized. For example, NASA's famous Apollo Program to moon took altogether 11 years and had a total budget of 25 billion US dollars, taking as much as 70% of the total annual space budget during its most critical years. The sum equals to around 3% of the total US annual budget during that year. Regardless of being an extraordinary example, it gives an idea how an individual space mission can differentiate itself from any other industry. [15] Missions and projects carried out in conventional way still represent the majority of space sector today. [16]

2.2.1 Role of standards, laws and documentation

According to SAE (Society of Automotive Engineers), 2017 is the 100th anniversary of the first aerospace standard, which included both aeronautics and early astronautics for the first four decades. [17] In the 1950's the situation changed as the launch of Sputnik-1 started the Space Age, and astronautics got separated from aeronautics. [8]

As government-driven space organisations started to widely interact with industrial partners, international standards were needed. Currently, there's a few major space standards that are being used world-wide, especially in Europe:

- The European Cooperation for Space Standardization (ECSS)
- ISO 49 – Aircraft and space engineering
    - Particularly ICS 49.140 – Space systems and operations

In addition to ECSS and ISO standards, there are multiple other standards applied world-wide, ranging from company-level internal standards to country and continent-wide ones. However, most of them are only in use in certain areas and fields, therefore they are left outside of this study.

Standards form the basis for conventional space industry, especially from suppliers point-of-view. Following the standards has been a pre-requisite for qualifying as a subcontractor for national space agencies. As space projects are often complex and have various stakeholders involved in them, the purpose of the standards is to assure the quality and minimize the risk of failure. A practical example is cable connectors: only certain limited connector standards are used in a project to make sure, that e.g. the devices and instruments fit to each other and the main structure of a spacecraft. [18]

The heavy requirements set by standards easily lead into using certain, often expensive electronic components, that tend to be technology-wise outdated. One reason for using components exclusively developed for space projects is the comprehensive testing, such as particle radiation tests, which is required in order

to guarantee the space eligibility of the component. The more tests the parts have been through, the safer the component is regarding overall certitude. [18] Another restrictive matter by standardization is related to project management. It is required by ECSS, and therefore basically applied in all ESA-related projects (i.e. most of the space projects in Europe), that the definition and detailed planning of the project is carried out prior to execution. Considering this, conventional space projects are very linear and changes throughout the project are kept to minimum. [19]

Space territories are areas without defined boundaries, therefore space-related law and legislation are applied on a very general level. From the legal point-of-view, the main purpose of the current international space law (*Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,* set by United Nations Office for Outer Space Affairs (UNOOSA) in 1996), is to ensure that any activity in space happens peacefully. [20] Since the treaty is very broad and fifty decades old, it rather works as a guideline for all space activities, unlike the safety legislations in automobile industry, for example. The actual acceptance of space-related activities is carried out together with multiple national and international institutions, and the process is strongly guided by major space standards, instead of law. [8]

2.2.2 Project life cycle in traditional space technology

As previously mentioned, projects in space industry are following a very linear model, often called the waterfall model. Ulrich et al. mention in their book Product Design and Development, currently the most cited work in the field of product development, that this model is good regarding project planning, scheduling and budgeting, for example. They point out that product development seldom goes according to original plans, and is therefore iterative by its nature. However, in the case of conventional space projects, this model is rather representative, as in most of the cases missions are unique and deployments have indeed only one chance. Furthermore, customer feedback, one of the main aspects in iterative product development, is basically non-existing as governmental institutes value mission predictability over technical breakthroughs. [19][21]

The waterfall model of different phases of space project life cycle is showed on **Figure 6**. The seven phases in chronological order are described as [22]:

- Phase 0: Mission analysis/needs identification
- Phase A: Feasibility evaluation
- Phase B: Preliminary definition
- Phase C: Detailed definition
- Phase D: Qualification and production
- Phase E: Operations/utilization
- Phase F: Disposal

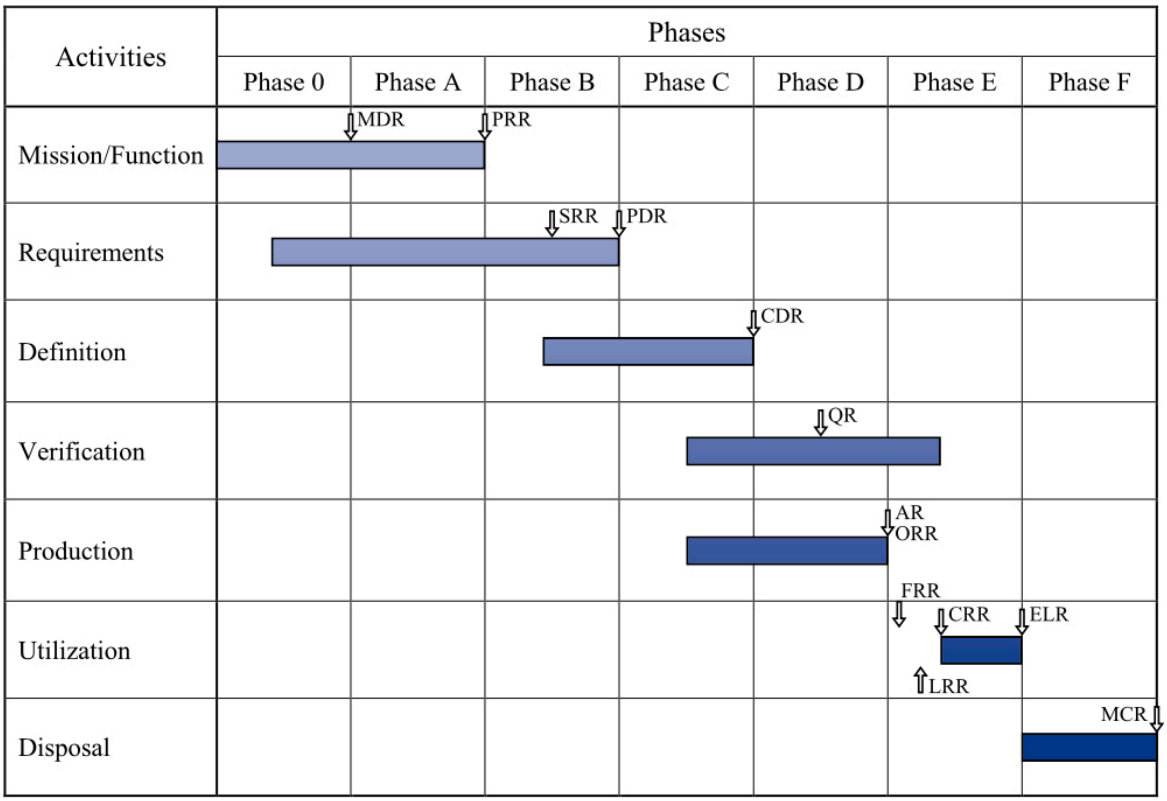

Figure 6 Waterfall model of space project life cycle, adapted from standard ECSS-M-ST-10C [20]

For guaranteeing the overall quality and to keep track throughout the whole process, the project is divided into key milestones, that are reviewed within all stakeholders (project initiator, contractors, different level suppliers, operators). **Figure 7** explains the flow of information in review cycles, including following compulsory reviews [22]:

- AR = Acceptance Review
- CDR = Critical Design Review
- FRR = Flight Readiness Review
- MDR = Mission Definition Review
- ORR = Operational Readiness Review
- PDR = Preliminary Design Review
- PRR = Preliminary Requirements Review
- QR = Qualification Review
- SRR = System Requirements Review
- WBS = Work Breakdown Structure

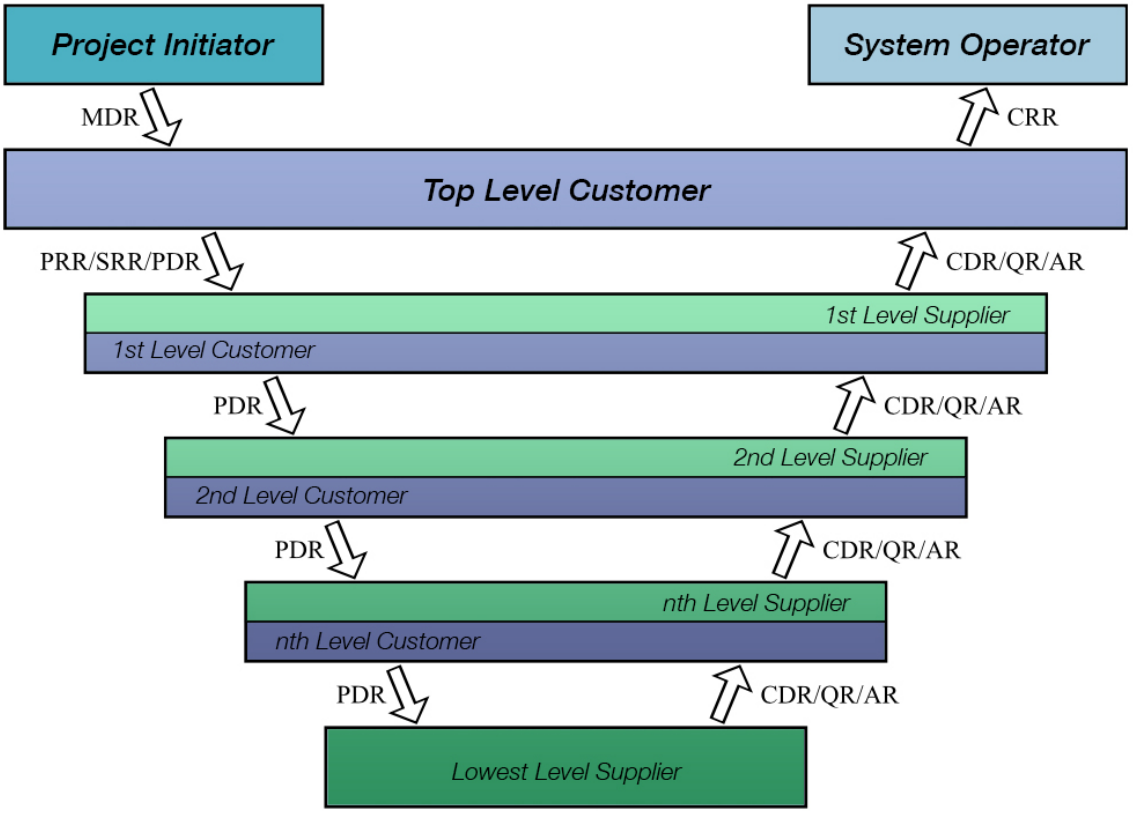

Figure 7 The information flow of reviews involved in a space project life cycle, adapted from standard ECSS-M-ST-10C [16]

To a great extent, these ECSS project guidelines rule how a conventional space company controls its production and plans the business. From a space agency's point-of-view, it is currently the most desired approach, as the emphasis is put into mission certainty and predictability. However, a great share of employees' time must be dedicated to fulfilling precise documentation requirements. While the documentation process is necessary for minimizing failure, it generates considerable costs. [19]

2.3 NewSpace – Activities in entrepreneurial space

In contrast to conventional space industry, some companies took a new approach for financing their business using private investments. This phenomenon, including the foundation of startups, i.e. new companies with high private capital seeds, utilization of new technologies and approaches, as well as convergence of commercial activities and space technology, is referred in the professional world as *NewSpace*. In other words, NewSpace, known in many other terms like *Space2.0*, *alt.space*, *entrepreneurial space* and *astropreneurship*, is a movement towards commercializing space industry in a competitive context. [16][23][24]

The first NewSpace companies, established in the early 1980's, were related to non-governmental space rocketry. During the time, some venture capital invested launces, like US-based Space Services Inc. (SSI), were able to eject payload into space. However, the development of their rocket got delayed, partly due

regulatory environment and government policy, and therefore the investment was withdrawn. In the beginning of the commercial space era, governmental agencies were merely seen as restrictions for business.

The situation is different today. Space agencies have realized that the prevailing model slows down innovation and therefore significant efforts have been put into accelerating new ideas and ways of working. National space programs offer their help in technology transfer and business incubation, enabling healthy competition to emerge within the space industry. [23] A good example of the governmental support for agility and paradigm change was NASA's Commercial Orbital Transportation Services program, initiated in 2005. NASA's own Space Shuttle program had come to an end and they had an urgent need to replace the service to guarantee vital supply and crew transportation to International Space Station (ISS). Therefore, the aim of the new program was to develop privately operated cargo system. By the end of the 500 million US dollar program in 2013, it had created extensive competition for companies that are still developing low-cost access to space. As result, NASA was able to concentrate governmental resources on scientific missions, like deep space mission. Furthermore, this changed the general mind-set towards commercial access to space – just like Apollo-11 proved already in the 1960's that human space travel is viable. [1][25]

On a general level, one big difference in the space industry that affects especially the development in NewSpace, is that big part of the development happens in software instead of hardware, following a global trend of software-driven advanced technology. In the past, it was space technology that accelerated software development – back in the 1960's, early computing was implemented in Apollo-program, allowing altogether 8 applications to be run onboard at any given time. Subsequently, the complexity of deep space missions increased, pushing major advances in autonomous software development. However, as the IT-sector outgrew space industry, today's achievements in software are being applied to space technology, which is often lagging behind due long development cycles and compatibility requirements. With capabilities and adaptability of modern software, it is possible to overcome the limitations of hardware in space use. During the past decade space industry has seen a new kind of convergence with space companies and the IT sector, that aims to create cost-savings using artificial intelligence in satellite operation, for instance. Several NewSpace companies are on a mission to fill the gap in the field of software. [8][16]

Modern icons of the new space era are widely known around the world. Companies such as SpaceX, Planetary Resources and Planet (previously known as Planet Labs) are showing the way for numerous of smaller companies that aim to be part of the growing industry. While most of the companies are focusing on lowering costs and therefore democratizing access to space activities, some are developing truly revolutionary missions, like asteroid mining, multi-thousand satellite constellations and colonising Mars. **Table 1** shows some of the most known NewSpace companies and their main field of operation. [26]

Table 1 Examples of NewSpace companies and their fields of operation [23][26]

NewSpace company	Field of operation
SpaceX	Orbital rocket launch, manned interplanetary spaceflight
Planet	Nanosatellite constellation, earth observation and analytics
OneWeb	Microsatellite constellation, space-based telecommunication
Planetary Resources	Asteroid mining
Nanoracks	Small satellite launch services, microgravity payload integration
Terra Bella (Planet labs subsidiary)	Satellite Imagery, video and analytics of earth
Virgin Galactic	Commercial spaceflight, suborbital tourism
XCor Aerospace	Private spaceflight and rocket engine development
Blue Origin	Sub-orbital spaceflight, spaceflight services
Celestis	Space burial

Despite NewSpace companies are playing with different rules, as they are not working directly for governmental institutes, drawing the line between the NewSpace and conventional space industry is not straightforward. NewSpace literature often mentions small and medium-sized enterprises (SME's), which ESA defines by the following criteria, set by European Union in 2003 [22]:

1. SME's size cannot exceed 250 employess
2. SME must have an annual turnover that does not exceed 50 million euros
3. SME's annual balance sheet total cannot exceed 43 million euros [27]

However, many of the current NewSpace companies, like SpaceX and Planet Labs are well beyond the SME-criteria, yet they are the often among the first companies mentioned entrepreneurial space presentations and literature. Instead of by company size, Autry defined in his long-term study on governments role in the formation of NewSpace communities, that only companies that are exposed to selection pressure are qualified as NewSpace companies. Therefore, government sourced companies, like the ones belonging to military-industrial sector, are excluded. [23] Other definitions have been made, also within the

sector NewSpace. For instance, Tauri Group, a company that collects data for official entities like NASA, outlined their research to *startup space ventures*. According to their definition, startup space venture means a company that has received and reported venture capital, seed funding or private equity investments, and that provides space products and/or services, mainly in:

- Manufacturing satellites, launch vehicles, or other space-based systems
- Manufacturing ground equipment
- Providing services that rely on these systems, such as satellite TV, radio and broadcast
- Providing analytic services based on data collected from space-based systems, either alone or in combination with terrestrial systems [28]

Besides of private funding, NewSpace companies are standing out from conventional space industry by their way of working and organizing. Many aerospace companies and especially space programs are organized in a hierarchic way following the traditional pyramid model. When collaborating with ESA, the role differentiation, set during planning of the project, should be strictly followed throughout the project. [8] ECSS standard on project management explains the organizational structure in the following way:

"The organizational structure provides a clear and unambiguous definition and allocation of individual roles and responsibilities together with the necessary authority to implement these within the internal project set–up as well as towards project external interfaces." [22]

In NewSpace industry, the organizational structure tends to be rather flat. In SpaceX, the biggest NewSpace company in the world, there aren't many steps from an engineer to the CEO Elon Musk, despite the previous startup having

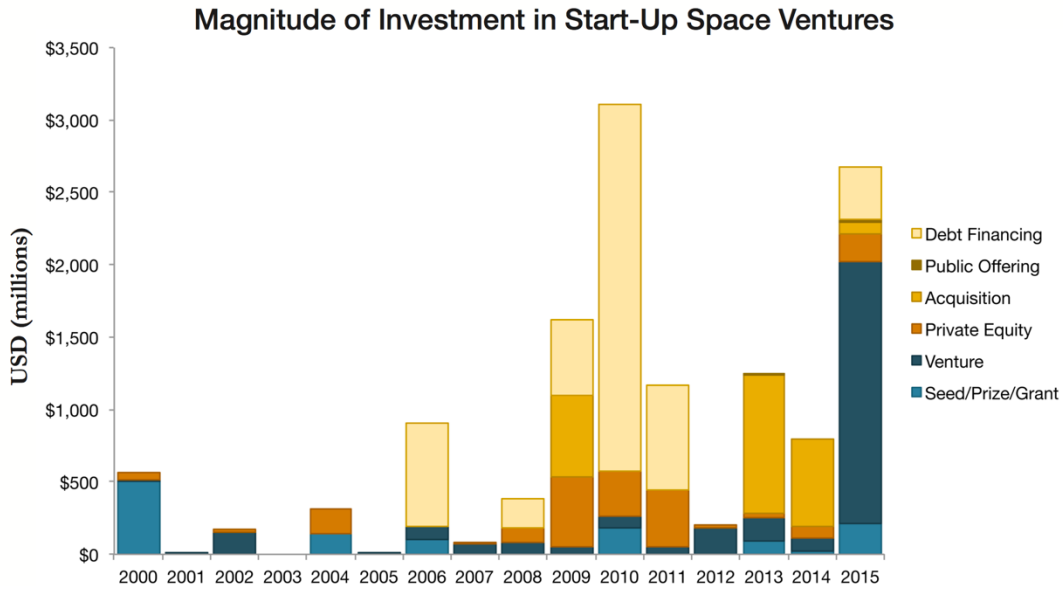

Figure 8 Investments in NewSpace industry startups divided into different categories [28]

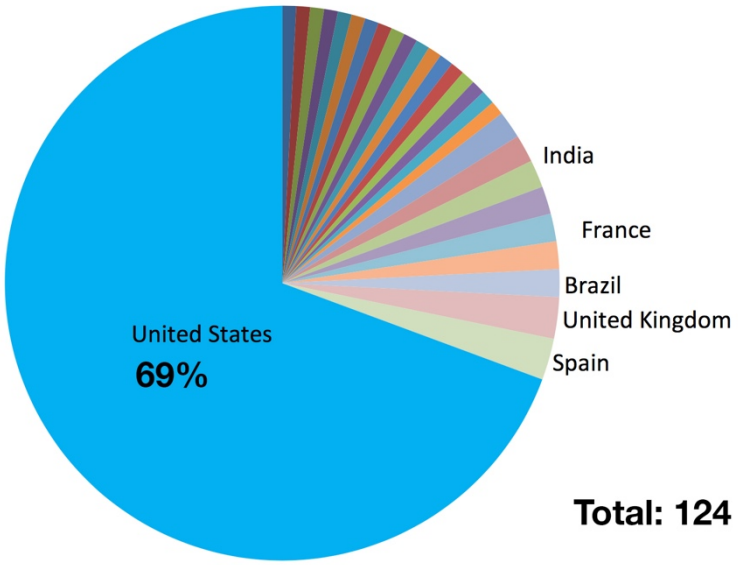

Figure 9 Geographic distribution of NewSpace companies in 2015, according to criterias by Science and Technology Policy Institute [32]

already 6000 employees. Huge rocket productions can change their shape on-the-go and *SpaceXers* are encouraged to reveal failures and problems immediately and informally, which are signals of flexibility and openness. [29][30]

The sector of privately funded space industry is growing fast. In 2015, NewSpace companies collected more venture capital (VC) than during all of the previous 15 years combined. [28] **Figure 8** shows the amount of investments and how they split into different categories. The dispersion in the figures indicate that annual total amount of investments truly depends on individual deals. For instance, SpaceX raised venture capital worth of 1 billion US dollars on its seventh funding round, covering around half of the total VC and over 30% of the total NewSpace investments during that year. Another remarkable peak in acquisition took place in 2013, when Monsanto acquired the Climate Corporation, a company that provides Earth imaging data to agriculture industry, for 930 million US dollars. [28]

Regardless of high growth, there's quite a few global trends and other considerations affecting NewSpace business. For example, 2016 faced many delays in launch services, causing multiple spacecraft producers to postpone their deployment to 2017, therefore having negative influence to R&D. [31] Due to uncertain factors, there's varying visions of the future of NewSpace industry. Most of the literature in the field seems optimistic about the continuous, yet descending growth during 2017-2020. However, investors are still undecided about the future forecast. For instance, in a Forbes interview carried out in 2016, Jeff Matthews, Director of Venture Strategy & Research in Space Frontier Foundation, stated that within the next 18-24 months commercial space might face a significant stagnation. This largely depends on whether NewSpace companies find ways to sell products in consumer-markets. [32]

In particular, US policy has a big influence on space ventures, as most of the NewSpace companies are located in the United States. Out of all the companies founded between 2000 and 2015, around 69% started in US. The total growth of the sector in US is expected to grow, since in the beginning of 2017 President Trump's administration announced that a bigger sector of NASA's budget will be allocated to commercial space activity. [33] This will likely have a global effect, as space is an undefined field, they the whole world as their market. **Figure 9** shows the geographic distribution, out of which UK and Spain have the second and third biggest share. [34]

2.3.1 The role of public sector in NewSpace

Despite being commercial by its nature, governments and space institutions play a big role in NewSpace industry. The companies of this new space era are both regulated and supported by governmental operators. It is worth noting, that governmental support does not limit to space agencies. For instance, universities and in general space education have a growing impact, especially regarding the small space crafts. Several of the new small satellite startups are spin-off's from university projects, where researchers also play a key role in R&D and innovations in space sector. [5][23]

As previously mentioned, space agencies have noticed the benefits and possibilities of commercial space industry. ESA promotes actively SME's and have a dedicated policy for space startups. Traditionally, small companies were largely seen as component providers in the supply chain of projects, which has been beneficial for countries lacking their own space program. ESA maintains an extensive SME Database, that provides visibility and easy access for European companies to reach international markets. Furthermore, their *fair return* policy monitors financial distribution of each member country, so that each country get their own perceptual share, that also increases the overall competitiveness. [19]

However, to get a contract, the company needs to go through long process of qualification procedures and proposal rounds, involving national delegations. Therefore, it is essential for a collaborating company to know the procedures and also have knowledge on the strategies and resources of competitors. [19] Currently ESA is renewing its policies towards more agile way, as small commercial ventures are facing problems in both R&D, as well as financial aspect due long waiting and strictly defined project plans. A practical solution for this is ESA's Business Incubator Centre (BIC), initiated by Technology Transfer Programme. BIC's are located in different cities throughout Europe and provide an entrepreneurial platform and network for SME's to discover and develop space technologies and apply them into non-space environment. [35]

Despite the importance of space agencies and collaboration, it is still noteworthy to understand the limitations when having government as the primary customer. This basically means that the company's schedule and eventually the whole business plan goes according to ESA's schedule. Furthermore, cultural clashes are likely to occur when the other party is implementing an agile entrepreneurial working approach, while the other one strictly follows standards and well-tried policies. [19]

2.3.2 Product development models and methods of NewSpace

The previously introduced linear waterfall model by ECSS fits well to certain situations. It is a good tool in planning overall development and estimating schedules, especially on complex missions. It's also easier to keep track with multiple suppliers and other stakeholders, which radically increases the overall success rate. However, entrepreneurial field plays with different rules. When offering a product or service for customers, mission development gets replaced by product development. To survive in the changing and competitive environment, flexibility is a must and without creative solutions and distinguishable approach it is hard to compete against the competitors. [18]

Agile methods were originally created for IT development. When the work happens in software instead of hardware, changes are easier to be tested and implemented to other sub-functions. By doing so, mistakes are found in the early phases of the project, meaning that it's also easier and cheaper to fix them. Agile methodology leans on iterative development cycles and learning by doing, on the go. Figure 9 shows the simplified model of iterative agile development. [18]

As a major part of NewSpace development happens in software, it is easier to implement agile methods to space products. This is the case specifically in small satellite manufacturing and development, as the whole satellite can be assembled and test-ran already in a very early phase. If the tests are made for the whole structure instead of only different sub-features, time can be saved in terms of avoiding compatibility issues and creating insight for final tests. Furthermore, it is easier to test assemble and apply constant changes of the mechanical parts in digital world, when structures are relatively simple, so all the changes do not need to be reported for multiple stakeholders. All of these methods dramatically saves the overall costs of development. [16][8]

Agile methods are not only used in small scale space projects. SpaceX is using similar methods in rocket production line. Instead of task management, they are using a collaborative management application, that also helps the whole factory and its hundreds of workers to prioritise critical aspects. As the production floor is flexible and operations are on constant move, even a 50-meter long Falcon 9 rocket can be laid down on its side for further operations. Obviously these kind of working methods do not go according to NASA standards, therefore SpaceX has created its internal working guides and the engineers are using them to push NASA to update their standards, enabling a dynamic collaboration. Also the way of counting development costs changes radically, as NASA estimated with their finance tool a price tag ten times bigger than the actual costs for Falcon 9. [29]

Despite being agile and flexible, NewSpace companies do to pay extra attention to documentation and testing. For example, launching services and deployment producers require comprehensive testing for guaranteeing, that a spacecraft does not cause any problems and endanger the other crafts or even the whole mission. All the testing procedures, along with critical parts of manufacturing, should be documented thoroughly. [8][19]

In conventional space technology, documentation consumes a lot of working time and therefore also resources. For bigger companies and institutes, systematic documentation might often make sense in securing quality and for knowledge transfer purposes. However, for a smaller company aiming for radical cost reduction, it often makes sense to minimize the documentation and bureaucracy. It should be made as easy and as straightforward as possible, so that the company can focus on doing practical tasks. [18]

Maintenance under space conditions is close to impossible – at least in unmanned space flights. Overall costs of conventional space missions are so high, that it makes sense to aim for 100% success rate. In contrast to avoiding failure, it is an essential part of learning in agile methodology. However, failures should happen as early stages of the product development process as possible, when changes do not cost as much. This is usually done by building mock-ups, prototypes and other low-tech proof-of-concepts. It might be financially desirable to fail on technology demonstrations, if it leads to a better outcome for the next version. This is possible since low-cost access to space is one of the core characteristics of NewSpace. Therefore fail is not only tolerated, but there's even a permission to do it.[37] Another desired outcome of low-cost prototypes are the unexpected outcomes, that often are an essential part of creative process. [21]

Developing commercial customer-oriented products brings several other factors as compared to developing missions or other publicly funded products. It is essential to adapt to changes in the markets, even in the middle of a project. Instead of multi-year projects

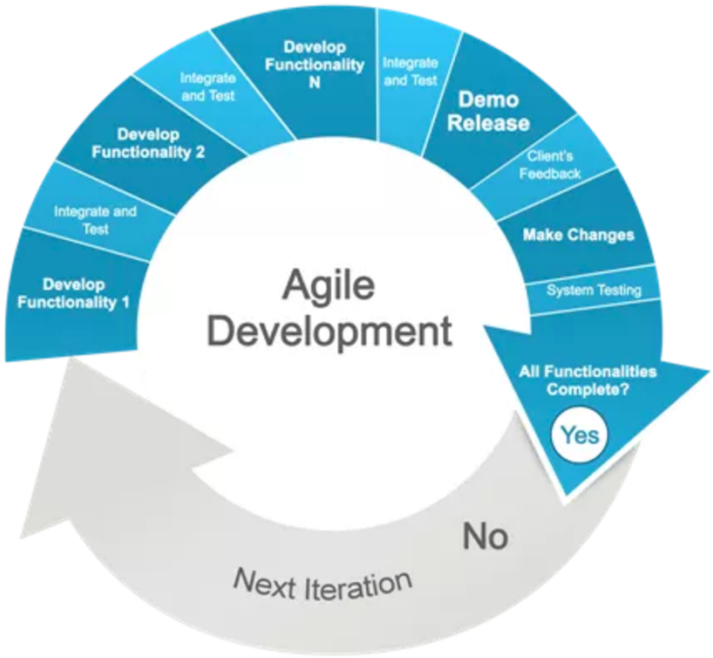

Figure 10 Simplified illustration on iterative agile development [36]

Figure 11 1-Unit, 2-Unit and 3-Unit CubeSat structures by ISIS (Innovative Solutions in Space) [39]

2.3.3 Nanosatellites – The icons of new space era

Mini-, micro- and nano-scale satellites have generally been seen as the icons of NewSpace.[16] They belong to small-scale satellites, which are classified according to the scale shown in **Table 2**:

Table 2 Small-scale satellite categorization [38]

Satellite class	Mass Range
Femtosatellite	10 - 100 g
Picosatellite	< 1 kg
Nanosatellite	1 - 10 kg
Microsatellite	10 - 100 kg
Small Satellite	100 - 500 kg

Due the case study of this study, the focus is mostly on CubeSat's, which are satellites consisting of 10x10x10 cm units, like the ones shown in **Figure 11**. These typically 1-12 unit satellites have gained substantial popularity during the past decade, due their relatively low price and modularity, that applies to design, building and deployment. [38]

The miniaturization of electronics is constantly creating possibilities to cut down the overall size of technical devices. This applies to space technology as well, however some physical and technical limitations, like power generation and

communication methods, outlines the capabilities of small spacecraft. Therefore, nanosatellites were in the beginning mostly limited to technology demonstrations and student projects – in 1999 the first CubeSats were formally introduced as educational platform to support hands-on experience in design, manufacturing, launching and operating of spacecraft. However, these small hand-on projects have spawned various innovations related to technical achievements and business approaches, especially in terms of niche use cases. In addition to multiple entrepreneurial spin-offs, CubeSat's have also been used in scientific missions. [39]

Small size and modularity of CubeSat's lead to major cost-savings in terms of access to space, design, manufacturing, testing and operational lifecycles. This creates a different approach compared to large satellites, as previously considered technical limitations can be overcome with quantity and agility. For example, multi-satellite constellations can provide similar resolution on specific cases of Earth imaging, but with higher refreshment rate. [39]

Currently, nanosatellites have access to space only as a secondary payload, therefore they are restricted by the missions and launches of conventional space industry. However, multiple companies are developing launch services dedicated specifically for small satellites. If managed to do so, the forecast of nanosatellite launches shown in **Figure 12** is estimated grow rapidly. [38][39]

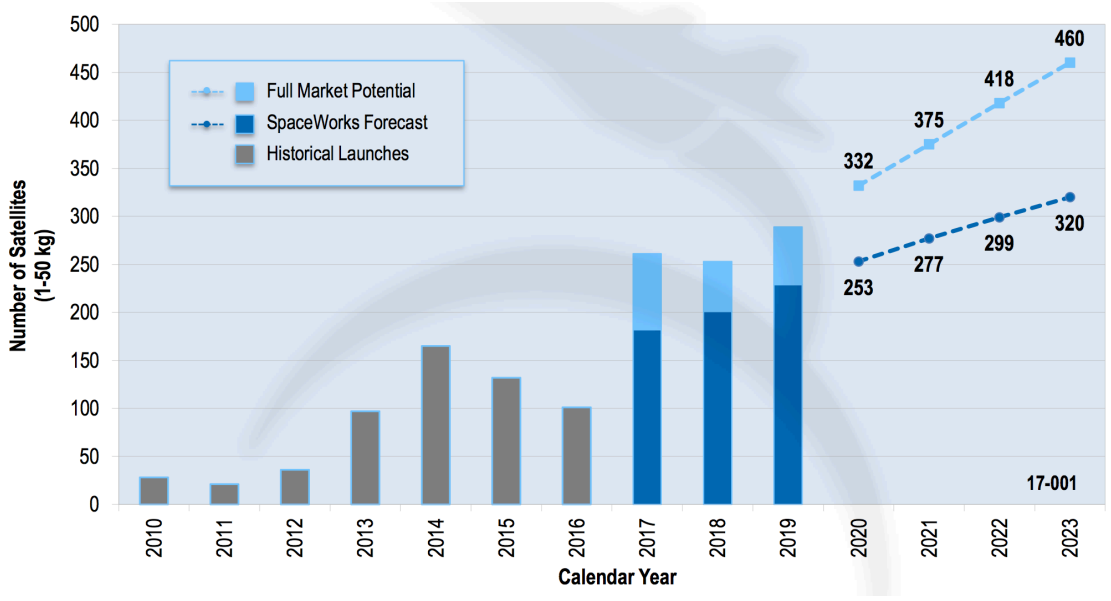

Figure 12 2017 Nano/microsatellite launch history and forecast [35]

2.4 Summary: Comparison of NewSpace and traditional space industry

As a summary from sections 2.1 – 2.3, **Table 3** shows a comparison between traditional space industry and NewSpace. These characteristics compose a basis of needs that are required for working according to NewSpace methodology.

Table 3 A summary of differences between conventional space industry and NewSpace

Conventional space industry	NewSpace
Missions	Products and services
Funded by public sector, driven by political decisions	Private investments, commercial income
Scientific research, safety	Profit, competitiveness
High-cost, mission specific budgets (>10M € projects)	Low-cost access, cost-efficiency (<200 000€ / satellite)
Public announcements, inspiration (for tax-payers)	Marketing point-of-view (for leads and customers)
Multiple stakeholders involved in missions	Internal development, external relationships
Hierarchical organizations	Flexible organizations, no requirements fo (standard based) roles
Long-term development (linear / waterfall)	Short R&D cycles (iterative)
Detailed mission design requirements set in advance	Tailored, need-based requirements
Careful pre-planning, low tolerance for changes during project development	Changes on-the-go, agile
Based on theoretical models, past knowledge and scientific	Constant practical testing, learning by doing
Following standards	Creating own methods, pushing new standards
Detailed documentation, knowledge transfer within big organizations	Minimum documentation, instant communication
Aiming for 100% success rate in all missions	Constant improvements by failing early and often
Space-proof, comprehensively tested components	COTS (Commercial off-the-Shelf) components, adaptation of new technologies
Hardware determines the software	Software-based development, fast adaptation of emerging IT solutions

3 Working environment

The world, as we see it, is under constant chance. This complex system of changing attributes affects to various matters, including the surroundings that enable companies to exist and fulfil their goals, i.e. working environment. In the context of this study, the sum of interrelationship between employees and employers, and the environment in which they operate, is reflected to the ongoing shift of space industry.

3.1 Scientific approach to the mechanism behind change

Economic, social and environmental challenges in the next decades are predicted to differ radically from the past, therefore there is a need to understand the world be are about to enter. By itself, *change* is a very broad and complex term. To interpret the change mechanism and to use it as a tool for adaptation in sense of working environments, it needs to be clarified and defined into a framework. [40]

Many economists and future researches have come to an agreement, that we are now experiencing the beginning of a new industrial revolution. During the shift of the 19th century, steam engine gave rise to the first Industrial Revolution. First industrial plants started the era of machine-made production, which among many others, introduced printing machines and therefore enabled extensive distribution of knowledge. Next revolution, also called the Technological Revolution, was induced by electrical power generation, rapid industrialization and new way of mobility, as railway and first automobiles were invented in the late 1800's. The current era represents the fall of unlimited growth and production of physical commodities. American economic and social theorist Jeremy Rifkin describes the Third Industrial Revolution as the converge of communication technologies and new energy regimes. His theory is endorsed, for example, by the European Parliament and implemented in various agencies. [41][42]

Another theory on the cycles of change was introduced by a Soviet economist Nikolai Kondratieff in the 1925. His theory does not exclude industrial revolutions; it rather specifies it according to his recognition of patterns. This model, renamed Kondratieff's waves after he passed away in 1939, consists of intervals between economic growth and recession. These cycles, lasting from 40 to 60 years, all begin with technological innovations, that affects the whole economic and social system. During the economic boom, productivity increases, but also value systems, social practices and organizational cultures are renewed. [40] **Figure 13** represents the Kondratieff's Waves appearing in synchronisation with yields of equity, by companies listed in Standard & Poor 500 index (S&P 500). This American stock market index lists annually 500 biggest companies according to its diverse weighting methodology. As one of the most followed equity indices, it is largely accepted as a leading indicator of economic cycles. [43]

Each cycle in Kondratieff's theory includes the following phenomena:

1. New industries emerge, replacing the old ones
2. A new, extended economic boom sets in with the rise of equity markets

3. New value systems begin to dominate, governing public debate and planning
4. New professionals and skill standards appear
5. New corporate cultures begin to dominate [40]

Therefore, the current sixth wave, which arose after the financial crisis of 2007–2008, is predicted to bring new ways of organizing and working, in other words demanding new working environments to support the emerging needs. In the past, the first and the second industrial evolution led to the development of modern organisation, that was very much inspired by the machines, in the core of the industrial production. According to a metaphor, the machine replaced human muscles during the Industrial Revolution. Following the same principle, digital technologies are doing the same for human brain power. Since the popularisation of internet, strengthening and popularisation of networking models have been used for understanding human communication and collaboration. [44]

According to Frederic Laloux, an author and societal influencer, the new organisational model consists of three basic principles. Firstly, self-management is taking over traditional organisations by creating order without hierarchies. Self-organising model is a common feature of complex and networked systems, like global economy or human brain. In practise, this would mean that teams would have autonomy in practicalities, like how they work and where they work.

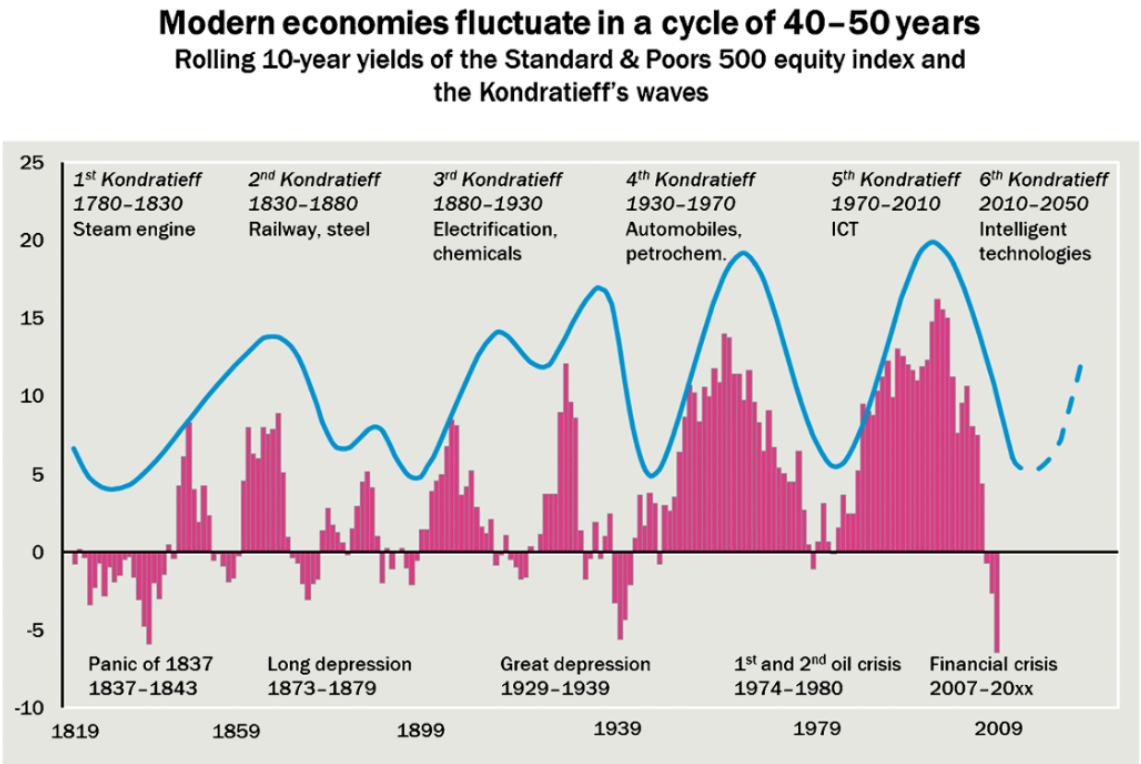

Figure 13 Kondratieff's waves synchronised with the yield of equity index of Standard & Poors 500 [37]

Secondly, consistency is going to take over dichotomy: In future organisations, there won't be need for separating home and work identities. Questions and calls for help are not only tolerated, but they work as a basis for collective learning. Thirdly, evolutionary purpose will define how organisations adapt to change. Previously, creating strategies was a task for the leadership, however in the self-managing organisations their task is to sense this natural tendency and provide a basis for supporting it. [44]

There are multiple reasons why hierarchical structures do not support modern environments. In dynamic organisations, old control and decision-making structures present several barriers for information flow, especially as the complexity constantly increases. For example, hierarchic model allows only the transfer of codified, formal information. Additionally, the layers of governance modify and filter information, which excludes weak signals and other uncertain, yet important types of information. Furthermore, as the complexity of hierarchical decision-making does not match the complexity of the environment, decentralization of decision-making fit modern organisations better. [40]

Multiple ongoing trends are already shifting the way we work. Artificial intelligence is replacing schematic work and the urge to replace natural resources with renewables calls for creativity and efficiency. As the population is growing, aging and globalising, the way of approaching work is changing, along with values driving the working culture. A management guru Peter Drucker has carried out multiple research projects related to modern ways of working. He introduced the term *knowledge worker*, a person that works primarily with knowledge, which is based on high degree of expertise, experience and/or education. [45]

Knowledge worker is a good example of a modern, networked and constantly learning persona. They differentiate themselves through their ability to understand context and act against established norms to create new solutions. To show continuous value, knowledge workers require unique tools and environments, as traditional environments and management techniques will not unleash the potential creativity. Furthermore, they are more connected to external environment as to internal teams. Currently, knowledge workers are believed to dominate most of the world's economies. They possess the intellectual value, that organisations must identify and harness in order to survive in the complex, increasingly competitive world. [46]

3.2 Working environment as a set of conditions

In the literature, there are various interpretations for the term working environment. However, most of the professionals agree, that working environment, also referred as work environment, or workspace environment, consists of the social interaction and the surroundings that provide the basis for working. According to ISO 9000, "work environment is a set of conditions under

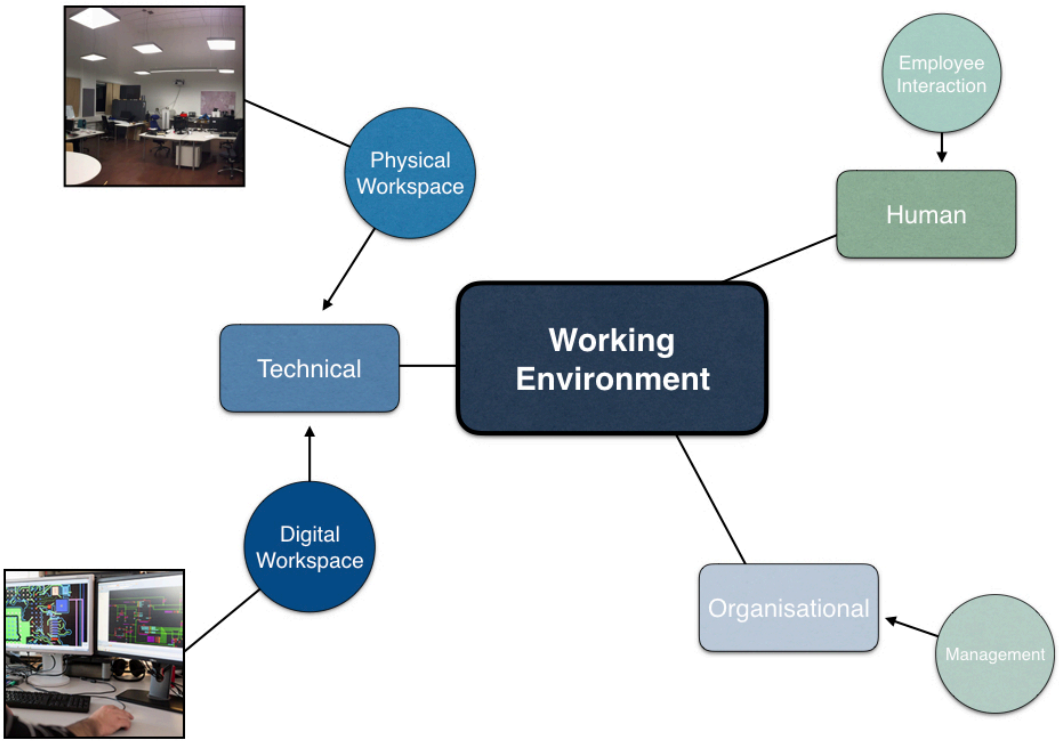

Figure 14 Working environment as a sum of three main components. [44]

which work is performed", with an addition: "these conditions include physical, social, psychological and environmental factors (such as temperature, recognition schemes, ergonomics and atmospheric composition)". [47]

However, for a more systematic approach, working environment has been introduced as an ensemble consisting of three main categories: technical, human and organisational environment (**Figure 14**). These themes are further discussed in the following sections. [48]

3.2.1 Technical working environment

Technical environment includes the physical surrounding where work is carried out, as well as digital workspace. The physical part can be further divided into technological infrastructure, tools and equipment. Especially companies, that focus on project-based working styles, have started to rethink the architecture of spaces. The more research and effort is put into this matter, the more it is understood that physical workspace steers action and provides a basis for experiences. [44][49]

Along with the change of working methods and communication mechanisms, workspaces are adopting the new ways of working, although often falling behind due lack of comprehensive understanding and planning. A good example – and a widely discussed, often emotional topic – is the open office. In the beginning of industrialisation, in early 20th century, workspaces were often strictly governed open areas, where employees were placed in a schematic order, in association to mechanical parts in production line. Later, in the 1950's, private rooms became a status symbol, a visible sign of progress in the career ladder. In general, the

rights of employees were taken into consideration in 1970's, and landscape offices became less popular. However, 1990's represented mobile ways of working and tools, that raised the popularity shared and flexible open office environment. However, especially in the 2000's, the new trend of bringing everyone in the same room, caused negative opinions as workers were not offered zones for privacy and ability to concentrate. Leaders sought settlement from turning the shared spaces into private rooms again, as it was known to work under familiar, previously functioning circumstances. [49]

The case of open offices represented a need for versatile, user-centred approaches in workspace design. Collaboration, aiming to achieve shared goals and sharing information becomes natural, when employees are offered spaces supporting different kind of activities. For example, ideation and shared conversations tend to get noisy. Considering outcomes, like the amount and quality of ideas, this is in many cases a positive sign of enthusiasm. Nevertheless, it often happens at the cost of harmony for the ones trying to concentrate. Therefore, designated spaces for noisy and quiet work are required for collaborative working methods. [49]

Other designated spaces include well-equipped and easily accessible meeting places, for example. By choosing a designated workspace, a person or a team can indicate whether they are available for spontaneous discussions or working on a work phase requiring concentration. It is also known, that to be efficient, human mind needs breaks from constant work-related thoughts. Therefore, refreshment areas should be designed so that they don't forbid work-related discussion, but rather encourages for non-work-related activities. [49][50]

In general, spatial design by itself does not provide a solution for a comprehensively functioning working environment. The gap between workspace solutions and the actual working process can be minimized using certain tools and methods, that helps to understand and improve the interaction and other desired outcomes. To promote a creative environment, spaces must balance between the following three factors:

1. Proximity
2. Privacy
3. Permission [51]

Proximity refers to close interaction between members of the community. Already in the 1970's Thomas Allen, an emeritus professor from MIT (Massachusetts Institute of Technology), made a famous research on how communication flows in technology companies. He carried out measurements related to probability for interaction and its relation to physical distance between the workers. The study revealed, that the probability for a weekly discussion is very low, if co-workers were located more than 10 meters apart from each other. Furthermore, being able to see each other was in direct correlation with whether the two people will discuss. **Figure 15** shows the results of this study, also known as the *Allen Curve*. Despite being carried out in the 70's, the curve still holds good largely today. The most effective workspaces increase proximity by removing barriers of bringing people together. [52][53]

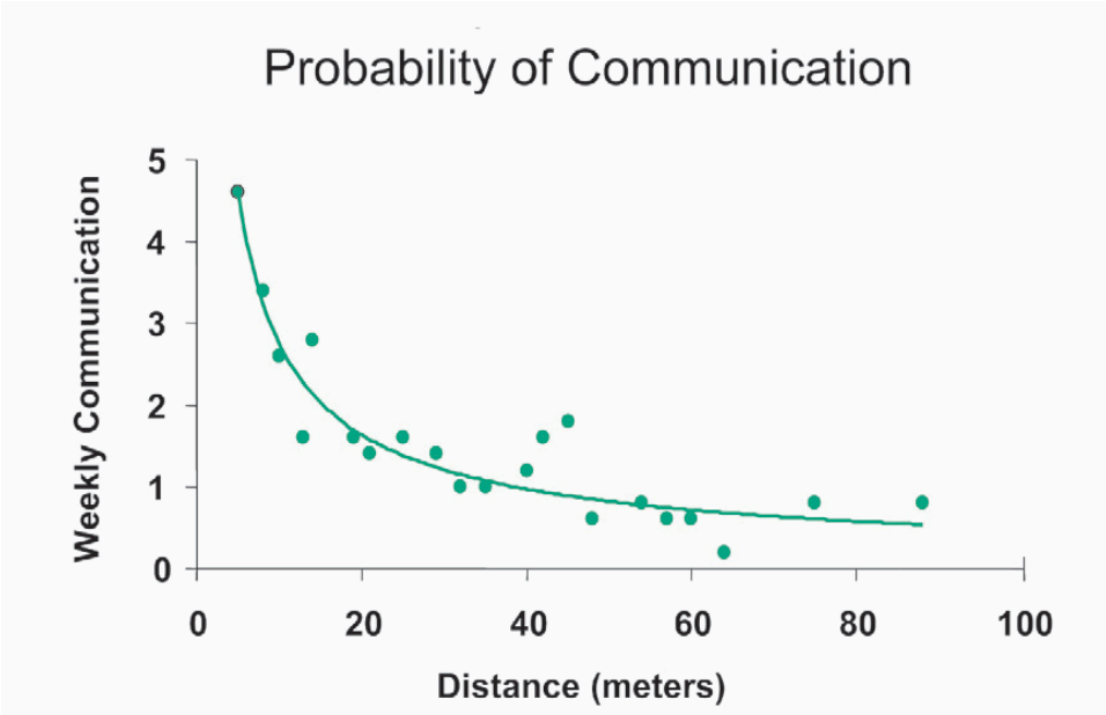

Figure 15 The Allen Curve – probability of communication in relation to distance between workers. [48]

Privacy is needed for both focusing and private work, but also for confidential discussions. Although it might seem counterintuitive, there are some research results indicating that informal interaction won't happen if people cannot avoid interaction when they want to. For example, in one case it was noted that colleagues in a shared office didn't want to openly share their thoughts and ideas due the risk of their manager overhearing them – despite the managers efforts to increase interaction. However, a shared photocopy room, that was located in the end of a hallway, provided enough visual and acoustic privacy for employees to have informal chats. Furthermore, problems like jammed paper or empty toner cartridges acted as stimuli for interaction, despite the status or the department of the employees. [53]

Both social and physical dimensions of permission guide behaviour in an environment. Nowadays it is understood, that a creative working environment should allow and even provoke dynamic movement and interaction between workers. For example, if a space has comfortable furniture like sofas and bean bags in addition to traditional desks, it indicates that natural ways of working are encouraged and the users of the shared space are allowed to find the most suitable ways for different activities. [51]

3.2.1.1 Digital workspace as an augmentation of physical workspace

The evolution of technology has remarkably shaped our ways of working. Nevertheless, physical workplaces are often outdated for digital working methods, that are always performed in a space of some sort. Furthermore, work shouldn't be restricted by technology – solutions should always support the goals and methods of activities. Especially networked and location independent work

requires specific tools to help minimizing the disadvantages of remote working, for example. [49]

Eventually all digital work relates to storing, processing and transferring of information. Out of these functions, the last one has quite a remarkable role in working environment, as most of the modern ways of working require digital communication. Email has been a common way of communication in workplaces for the past three decades, and it is still the most used form of digital work-related communication, despite having kept its form largely the same. [54] It's a good way to communicate remotely and time-independently, however it can be rather time-consuming and much of information is being left out. The current trend among virtual communication is instant messaging, that allows real-time commenting and efficient delivery of ideas and data. [55] Among employees, instant messages are seen as informal and less work-related, therefore the way of using them is also more natural. Another benefit of instant messaging is that some applications provide location-details, which has been showed to decrease the feeling of physical distance and increasing proximity. [49]

Another tool to decrease the gap of physical distances is real-time video meetings. It delivers the facial expressions and other non-verbal elements that are otherwise excluded in remote interaction. However, research shows that video meetings still do not compete with actual real-time meetings, mainly because of technical limitations and challenges. Therefore, it should be also taken into account, that video communication requires certain attributes from the physical space, related to acoustics, lighting, furniture setting and bandwidth capacity, for example. [49]

Despite the age and popularity of the communication method, right combination of solutions should be implemented according to organisational needs. Investing in research on digital alternatives can lead to savings in terms of time consumption, misunderstandings and frustration. [49] Furthermore, the three affordances mentioned before, i.e. proximity, privacy and permission, are relevant to digital environment as well. They shape the way of working, interacting and eventually achieving the desired goals. Therefore, digital working environment should be planned and developed in harmony with the physical surroundings. [53]

3.2.2 Human environment

Human environment covers the human resources, as well as the social side of working environment, including employee and management interaction, teams and work groups. Furthermore, some literature also takes into consideration the external working networks that interact with company. [48]

Naturally, human environment is very complex and cannot be defined and interpreted as precisely, as the technical environment. For this study, a relevant part of human environment is related to the flow of information, as it's one of the key elements of the modern organisations representing changes in the Kondratieff's sixth wave. The ways of sharing and co-creating information affects not only the outcomes, but also aspects like productivity, employee morale and

work commitment. [56] In addition, one of the most influential human aspect or working environment is attitude, as attitudes can form the biggest barrier to change. [57] These matters will be further discussed in the becoming sections.

3.2.3 Organisational environment

Organisational environment consists of management procedures, working methods, shared values and philosophies. These systems include structural and procedural dimensions, like hierarchy and practical ways of working, out of which a good example is previously mentioned agile methodology. [58]

The evolution of working environment always requires the support from management point-of-view. Furthermore, this support should be openly discussed and included in the company's strategy from the very beginning. For example, decentralized collaborative methods can be very dysfunctional, if not enough flexibility is included in the operation. [49]

The basis of organisational environment leans on *company culture*, which refers to organisations customary methods of doing things, as well as the philosophies, values and assumptions underlying these matters. Company culture is a wide concept that can be used for understanding organisational phenomena, which is fundamentally needed for creating change. Therefore, company culture is the driving force behind all work-related activities, including decision-making and every-day operations. [57]

3.2.4 Tools and methods for comprehensive development

Working environment should be understood as a comprehensive complex of technical, human and organisational aspects. For building and maintaining a desired environment, is essential to find a balance between these three aspects. There are several examples of unsuccessful attempts to turn a traditional working environment into a modern, innovative one. [46]

For finding the required balance, several tools and methods have been developed, one of them being involvement of users of the environment for planning, implementing and further developing. This method of involving community in the design, called *participatory design*, has its roots in Scandinavia, where it was realised, that the mismanagement of physical environment was one of the major reasons behind social and economic ills. It is now understood, that the main source for satisfaction is not a solution that suits best for the needs, but the feeling of having been involved and influenced to ideas. Therefore participatory democracy is an effective solution for public institutes, but also local communities, like workplaces. [59]

In the process of designing working environment, multiple stages benefit from including employees and other stakeholders. The most popular method for this is a workshop, that can be outlined to cover either a specific area, or it kept slack for keeping the main focus on the participants, instead of solutions. [49] For example, in idea generation multiple angles of view help to see the big picture. Therefore, the more people join in, the richer the ideas tend to get. In addition,

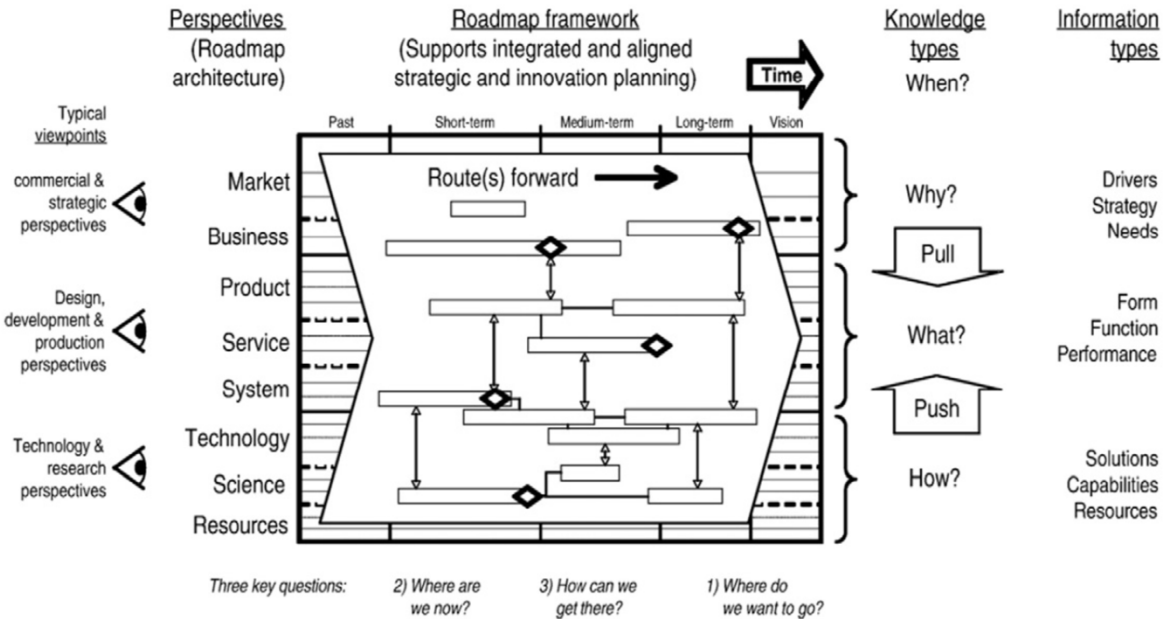

Figure 16 Example of a multi-layered business roadmap as a basis for creating a future scenario [60]

personal attributes, like attitudes can be included in observation. Other stages of working environment design include proposal reviews, opinion measurement and disseminating information. [59]

A good example on participatory design is related to LudoCraft, a Finnish game developing company, that moved into new premises in 2009. Before moving in and designing the new environment, they concluded that the new facilities should support creativity and general enthusiasm towards working. To reach the goals, the company arranged a set of workshops involving all related stakeholders, in this case employees, management, architects and even the property owner. As the company had plenty of game designers available, they used their self-developed 3D-tools to create multiple versions of the becoming space in virtual reality. This encouraged the users of the space to try out various solutions and therefore got them encaged into the project. After implementation and evaluation, the result was proven to enhance the quality of work and increase creative ideas. Furthermore, the space was designed to be flexible for future variations. Also the customers enjoy themselves in the space, which further contributed customer relationships. [49]

While the previously described change was extensive, improving working environments can and should also happen at a smaller scale. For example, putting communal effort into re-arranging an office gives participants a chance to experience the change. Prototyping arrangements has proven to shape attitudes towards flexibility, positively influence to new ideas for constant change and also increase the feeling of participation. [50]

Other tools include future scenarios, strategy maps and social networking analysis, for example. While the last one might require special knowledge and effort of implementation, and therefore turn out to be heavy for internal purposes, the first ones are easier to be implemented on. [49] Future scenarios can be used

as a tool for planning flexible environments not only for the present, but also for future use cases. Often businesses will anyhow conduct some sort of future scenarios for other purposes, like estimating forthcoming markets and business cases, so these can be used for work environment improvements. If not, creating one will most probably turn out to be useful in other cases. **Figure 16** shows an example of a multi-layered business roadmap, that can be used as a basis for a comprehensive future scenario for businesses. It utilizes a method called PESTLE, which helps to include six main forces that form an extensive overall picture in scenarios: political, economic, social, technological, legal and environmental. [60]

A strategy map can be used for outlining the ideas and ways of working. It can include pre-determined meters and desirables, as well as goals for organisational methods. Strategy map can be utilised according to different vantage points, like working environment as a symbol of company culture or specified challenges related to working environments. [49]

It should be noted, that whichever participatory tool is chosen, emphasis should be put on implementation and communication. If conducted in a poor manner, participants can see it as a “waste of time” or “nonsense”. These opinions obviously have a negative influence on the results as well. [50]

As a general tool, **Figure 15** shows a framework for iterative working environment design. The steps are shortly described below [61]:

1. Strategic: Vision, desired outcomes
2. Process of creation: Planning, involving users, implementation
3. Physical space: Physical outcome of the design process
4. Process of use: Actual use cases of the process
5. Realised intent: New working environment
6. Evaluation: Observations, measurements and feedback

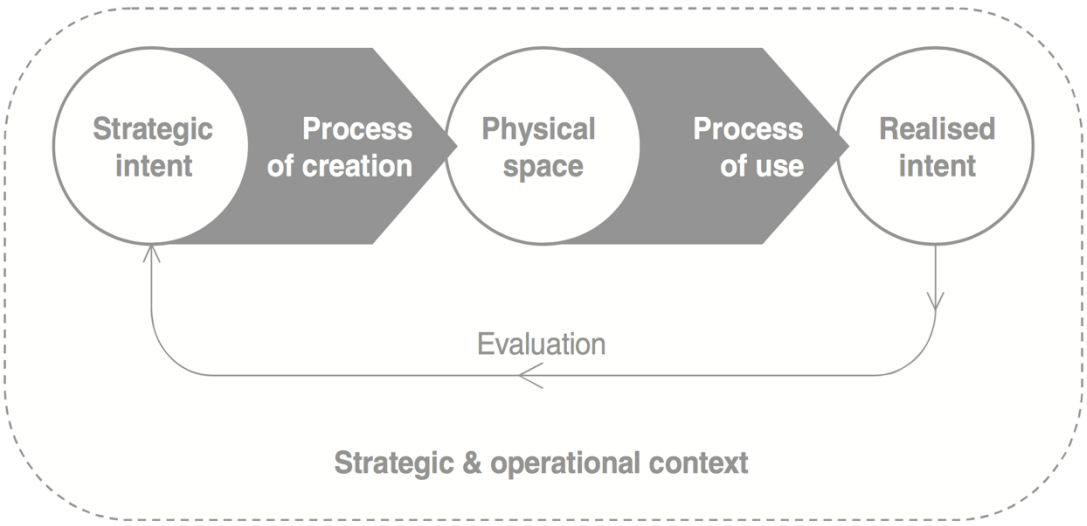

Figure 17 Strategic and operational framework of designing a working environment [60]

After the last step, evaluation, the next round of development can be begin using the added knowledge and results of the previous one. Despite being very general and simplified, it is very suitable for universal guidelines and as a tool for dividing a bigger process into smaller pieces. [61]

3.3 Desired values and outcomes of a modern working environment

Historically working environments often took influence from industrial approach – employees were working on continuous tasks on strict schedules. Therefore, that way of organizing is referred as the machine metaphor, as the mechanical structures replaced human muscle. For long period of time, the attitudes towards work remained the same. However, in the 1980's-1990's, working environments faced a large-scale shift, as more human approach was largely taken into consideration. [37] Nowadays it is understood, that in the future productivity cannot be any more measured using scale of production or sales. The reason for this is that due immense trends, like shifting from products to services, and limiting the use of natural resources, are influencing on criterions for profit. Therefore, new ways of management should be applied on companies aiming to survive in the markets of the future. [46][58] **Table 4** highlights some of the differences between classic and modern management methods. [37]

Table 4 Differences of traditional and modern working environment culture to highlight the ongoing change [37]

Classic scientific management	New school of management
Focus on processes	Focus on people
Hierarchies	No formal hierarchies, meritocracy
Obsessed with success	Learning from failures
Using known success	Finding new remedies
Immediate action	Immediate reflection
Enforcing unformal behaviour	Encouraging different opinions
Bias towards experts	Empowering employees to use their experience
Future as projected visions and plans	Allowing room for self-organization
Control mechanisms, leaders and managers	Values, culture, collective control
Planning	Future as emergent, ever-present, multiple-ontology space
Motivation by external motivators	Internal motivation

As a conclusion from the **Table 4**, as well as phenomena described in Chapter 3.1, some of the main desired attributes of a modern working environment are listed and described below:

Creativity

As previously mentioned, due shift of work, as well as tightening competitiveness on global markets, creative solutions are longed-for any company, regardless of field of operation. This can be already seen today in terms of traditional corporates and public institutes searching desperately for solutions to renew previously working models, that are exponentially producing less yield. [52]

Dr. Teresa Amabile, Director of Research in Harvard Business School, has carried out research on the relationship between working environment and creativity for the past 35 years. Her conclusion on the topic, shown in **Figure 18** is that creativity consists of three within-individual components, that exist inside a larger, external environment, which in this context refers to working environment. [62]

The skills are domain-relevant, consisting of:

- Knowledge & expertise in the field of operation,
- Relevant technical skills, and
- Talent & intelligence. [62]

The processes, on the other hand, cover further personal cognitive styles and characteristics of personality, for example:

- Independence,
- Risk-taking,
- Taking new perspectives on problems,

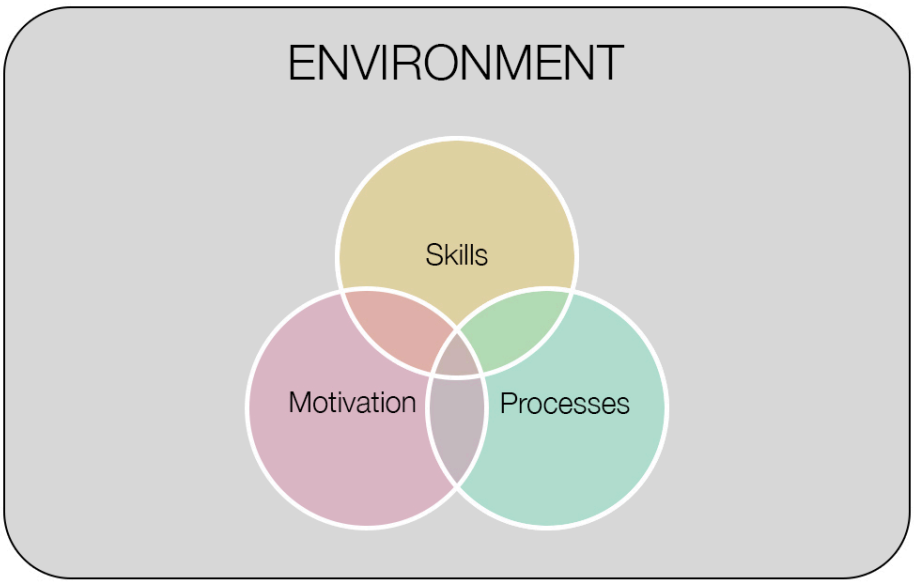

Figure 18 Main components of creativity according to Dr. Amabile's findings during her 35-year research on working environments and their impact on creativity [61]

- Disciplined work style,
- Skills in generating ideas,
- Ability to break out of perceptual,
- Self-discipline, and
- Tolerance for ambiguity. [62]

According to Amabile's theory, the motivation is task-related and driven by passion. Therefore, instead of aspects known to drive external motivation, like monetary rewards, surveillance, evaluation or requirements, the motivation stems from interest to undertake a task because its personally challenging, involving or satisfying, for example. Furthermore, one of the key stones of the componential theory of creativity, is that individuals are most likely to release their creative potential when they are driven by internal motivations listed before.

Partly inner motivations, but especially the externals ones, are based within the concept of working environment. In worst case scenario, working environment, especially the organisational one, is working as a blocking barrier for creativity. On the contrary, as its best, the working environment can help creativity to flourish. **Table 5** lists some of the barriers and enabling characteristics relevant to creativity in working environment:

Table 5 Barriers and enablers of creativity in working environment, according to Dr. Amabile's Componential Theory of Creativity [61]

Barriers of creativity	Stimulators of creativity
Norms of harshly criticizing new ideas	Sense of positive challenge in the work
Political problems within the organization	Work teams that are collaborative, diversely skilled and idea focused
Emphasis on the status quo	Freedom in carrying out the work
Conservative, low-risk attitude among top management	Supervisors who encourage the development of new ideas
Excessive time pressure	Top management that supports innovation through a clearly articulated, encouraging vision
Formalized communication	Appropriate recognition of creative work
	Norms of actively sharing ideas across organization

A good example on a creativity fostering working environment is IDEO, one of the most famous design companies, founded by David Kelley, a professor in mechanical engineering in Stanford University. Results on multiple different research carried out in IDEO confirm, that it's facilities support creative activities through its habit of visualisation, model making possibilities and provision of

suitable resources, for example. IDEO has put vast effort into synchronising it's physical environment into its culture, which supports constant informal interaction, leading into open sharing of ideas, being an essential part of a creative process. The design of their space, combined with ways of working and attitudes, communicate possibilities rather than control, or change implemented from above. [51]

Efficiency

The limitations of natural resources, major concerns related to climate change and shift of consuming from products to services are changing how companies see and use their resources. During the first and second industrial revolutions, companies were opportunistic about limitless growth, which equalled to increasing profits. According to various future studies, the growth of the future is happening in terms of efficiency, both resource and cost-wise. [37][42]

New solutions are a key element regarding intelligent use of resources. For example, efficient use of energy and materials provides savings not only in production costs, but also create new business models. Therefore, working environment should support and encourage towards efficiency – not in terms of increasing workload and exhaustion, but rather in terms of seeking alternative solutions and constant improvements. [40]

Productivity

Closely related to efficiency, productivity has always been one of the main drivers in work environments – one of the best examples being Scientific Management, or Taylorism, according to its creator Frederick Taylor in the shift of 20th century. By observing work and carrying out wide amount of empiric tests, he succeeded to optimize productivity, for example by letting workers to have more breaks in contrast to existing believes. While Taylorism mostly applied in manual labour during the rise of mass production, it is still largely seen as a paragon in modern management theories. [63]

Today's view of productivity in relation to working environments is shifting towards the amount of improvement from previously measured production. Being clear, that working environment affects productivity, surprisingly little research is focusing on the topic. According to a study conducted by the Nordic Council of Ministers in 2014, they were among the first ones to comprehensively analyse this relation. The research provides comprehensive data of work environment related matters that influenced on productivity in Nordic countries. Outcomes of the study were clearly indicating, that working environment and work wellbeing are positively correlated. Furthermore, statistically working environment is a significant predictor of productivity. [64]

Another study analysed FAVI, a French brass foundry, which faced a radical organisational transformation in 1983, when it's CEO changed. This courageous and inspired leader raised the status of the blue-collar workers by reshaping status symbols, like high-floor private office rooms and even luxurious toilets, that were previously only in the use of managers and engineers. He changed the

pyramid hierarchy to small sub-teams, that run their operations like their own small companies, something previously unseen in heavy production industry. Without an executive team, the company managed to grow sustainably and while all the European competitors lost their business or moved to China, FAVI constantly increased its productivity, while staying competitive even compared to Asian pricing policy. Today, FAVI is the world's leader in cuprous alloy injection industry. [44][65]

Flexibility

Due mobile and variable nature of work, a modern working environment should support flexibility. Already in the planning section, possibilities for expanding or downsizing should be taken into consideration. Furthermore, spaces supporting various kind of activities only work when the operational culture is flexible enough; in other words, moving in and moving out should be easy and encouraged. [66][49]

Research shows, that flexibility in terms of workspace provokes fluid and creative thinking. In one example, that took place in venture capital firm called Y Combinator, employees gathered together in a basic prototyping workshop, where they were provided basic materials, like cardboard, duct tape and post-its. Prior to workshop, the organiser created simple cardboard cubes that served as chairs. As the cubes created a contrast of otherwise polished workplace, a lady took one of the boxes and asked, whether she can use it as part of her prototype. Rather obviously, she was allowed that, despite it didn't belong to objects provided. This simple example shows, how the roughness and feeling of temporariness of a space can encourage taking the space under control and transform it into something else. Ignoring the "givens" and altering the environment changes also the way to think about traditional challenges. [50]

Another example of extreme flexibility and dynamism of workspace is the main office of Valve, another game developing company. All the office desks and chairs have wheels under them, enabling easy and rapid movement according to projects, by just unplugging electricity. The developers can even vote with their feet, as the company is fully self-organized. This also has an influence on the mind-sets and therefore a positive impact on creativity. [44]

Trust

As modern organisations are becoming more agile and decentralised, more emphasis is being put into trust. Have less control attracts certain kind of individuals, who are motivated and inspired towards working. Furthermore, having social control above traditional "command and control" management structure engages people not just to deliver good quality of work, but also to rethink and improve the given organisational structures and ways of working. [67]

According to a study, that involved 30 companies around the world in 2006, roughly half of the managers don't trust their leaders. This is a major problem as low levels of trust may lead into stressful and unproductive working environments.

Furthermore, distrust dramatically decreases tolerance for risk-taking, which negatively affects the innovativeness of the whole organisation. [68]

So, creating a flat organisation requires trust. Additionally, another study states that having trust in organisation, leads to open discussion and transparency. As a positive side effect, increased trust increases fun and therefore also boosts work satisfaction. [67][69]

Attractiveness

Organisational forerunners have understood, that work facilities are a competitive advantage and part of the brand. While it is a challenge to prove it, pleasant ambience, combined with supporting methods and activities, has shown to increase productivity, collaboration and enhance customer relationships. [49]

For example, there's proof that cosy atmosphere support natural interaction – when people act in environments which they associate to joy and relaxation, like places similar to park or home, they also tend to shape their ideas and communication accordingly. While it is definitely not suitable to all kind of work, it can improve some sorts of tasks that require less concentration and more freedom. [50] Additionally, another research shows, that workplaces that satisfy the creative needs attract more creative technology and knowledge workers. However, the study adds that providing a healthy work-life balance becomes increasingly more important than the attractiveness of the workplace. [70]

3.4 Measurability of working environment

The biggest challenge in the change of working environment are attitudes. Therefore, it is essential to collect measured information to support for pushing the change. [49] Research has shown direct correlation between many improvement aspects of working environment and financial profits. Furthermore, the ongoing change of generation is ought to have a positive influence on the attitudes towards change. [49] This chapter offers different tools for measuring a working environment.

3.4.1 Leesman index

The Leesman Index is the largest independent measure of working environment, especially in terms of work effectiveness. By 2017, the index had been used for analysing over 2000 different offices, during which over 260 000 employees in 67 different countries had answered their questionnaire. [71]

Using their own online form, Leesman collects data among organisations with the focus on how well the working environment supports employees in their work. This data is used for measuring and benchmarking effectiveness mainly focusing on physical working environment. The main goal is to understand individual preferences, which often vary within organisations and might be very different from the planner's aspects. [72][73]

The limitation with Leesman Index, regarding working environment as a sum of technical, human and organisational aspects, is that it focuses mainly on physical surroundings. However, many conclusions can be drawn from its activity-related pattern recognition, which creates human- and organisation-related connections between different sections. Furthermore, Leesman Index has a vast, constantly growing field-specific data base, that helps to compare results regionally, or world-wide. [73] **Figure 19** shows examples of Leesman Index conclusions, that also indicate the strong need for improvements. [71]

3.4.2 DICE framework

Another tool for measuring nebulous matters is called DICE framework. This method, originally developed by Boston Consulting Group, aimed to fill for the substantial need to measure subjective matters, particularly projects related to change. One of the main benefits of the tool is that it initiates genuine communication inside the organisation, yet being cost and time-efficient due its simplicity. Currently it's the leading indicator of the success likeliness in project management. [74]

The term DICE comes from duration, integrity, commitment and effort. Duration (D) means either the time of completion or time between milestones, set for a specific project. Integrity (I) relates on the duration by indicating the ability to complete the process in time. Commitment, on the other hand, is divided into two parts: In terms of working environment, for example, management team's commitment (C_1) refers to the most influential executives driving the change. The other part of commitment (C_2) covers people, who are affected by the change.

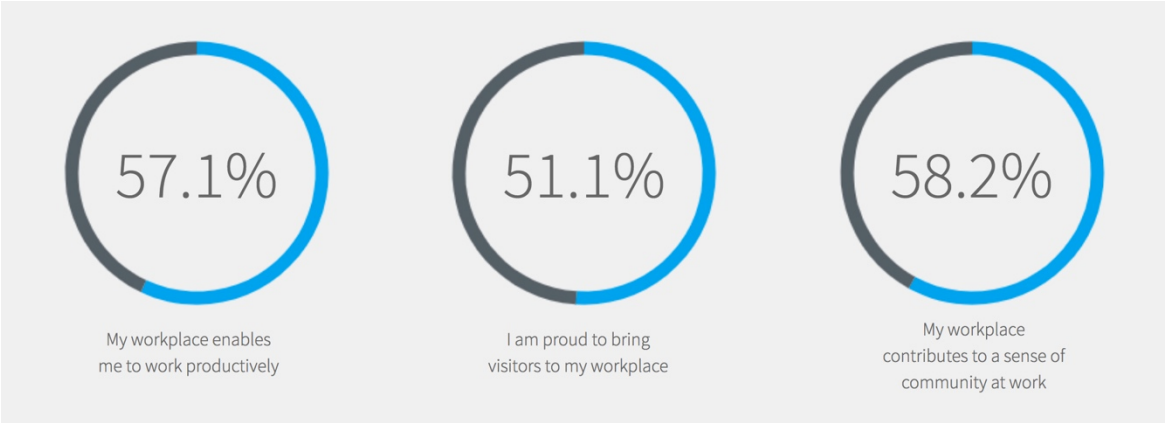

Figure 19 Highlighted conclusions of global working environment statistics by Leesman Index [71]

Effort (E) a factor highlighting the fact, that all transformation requires extra work, which should be taken into consideration already before any implementations are taken into action. [74][75]

DICE score is calculated using a simple formula [75]:

$$DICE\ Score = D + (2 * I) + (2 * C_1) + C_2 + E$$

Each factor is given a score between 1 to 4, with 1 being the best and 4 being the worst. While the number strongly depends on the executive making the calculations, DICE framework provides tools to support the decisions. **Table 6** summarises the outlines provided by Harvard Business Review [74]:

Table 6 Guide for DICE scores by Boston Consulting Group / Harvard Business Review [74]

Factor	Questions	Score
Duration (**D**)	Do formal project reviews occur regularly? If the project will take more than two months to complete, what is the average time between reviews?	If the time between project reviews is less than two months, you should give the project 1 point. If the time is between two and four months, you should award the project 2 points; between four and eight months, 3 points; and if reviews are more than eight months apart, give the project 4 points.
Integrity of performance (**I**)	Is the team leader capable? How strong are team members' skills and motivations? Do they have sufficient time to spend on the change initiative?	If the project team is led by a highly capable leader who is respected by peers, if the members have the skills and motivation to complete the project in the stipulated time frame, and if the company has assigned at least 50% of the team members' time to the project, you can give the project 1 point. If the team is lacking on all those dimensions, you should award the project 4 points. If the team's capabilities are somewhere in between, assign the project 2 or 3 points.
Senior management commitment ($\mathbf{C_1}$)	Do senior executives regularly communicate the reason for the change and the importance of its success? Is the message convincing? Is the message consistent, both across the top management team and over time? Has top management devoted enough resources to the change program?	If senior management has, through actions and words, clearly communicated the need for change, you must give the project 1 point. If senior executives appear to be neutral, it gets 2 or 3 points. If managers perceive senior executives to be reluctant to support the change, award the project 4 points.
Local-level commitment ($\mathbf{C_2}$)	Do the employees most affected by the change understand the reason for it and believe it's worthwhile? Are they enthusiastic and supportive or worried and obstructive?	If employees are eager to take on the change initiative, you can give the project 1 point, and if they are just willing, 2 points. If they're reluctant or strongly reluctant, you should award the project 3 or 4 points.
Effort (**E**)	What is the percentage of increased effort that employees must make to implement the change effort? Does the incremental effort come on top of a heavy workload? Have people strongly resisted the increased demands on them?	If the project requires less than 10% extra work by employees, you can give it 1 point. If it's 10% to 20% extra, it should get 2 points. If it's 20% to 40%, it must be 3 points. And if it's more than 40% additional work, you should give the project 4 points.

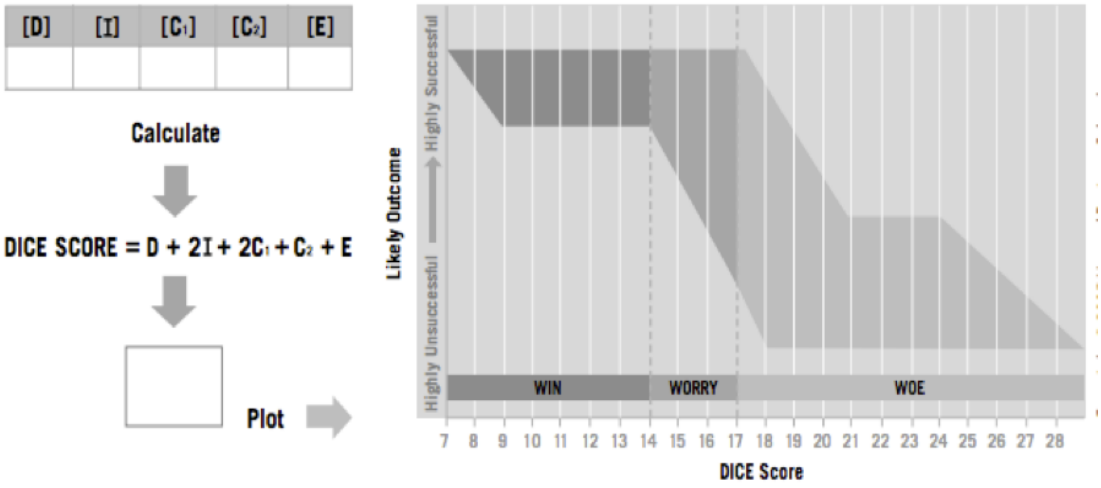

Figure 20 DICE Framework and score distribution [74]

The resulting DICE Score ranges from 7 to 28. The scale, shown in **Figure 20**, tells how likely a transformation process is going to succeed [74][75]:

- 7 – 14: Highly successful (*WIN zone*)
- 14 – 17: Unpredictable (*WORRY zone*)
- 17 – 28: Unsuccessful (*WOE zone*)

While DICE framework is not suitable for working environment as itself, it's a practical tool to assess direction. This is very useful, as the projects related to working environment are somewhat always related to change and transformation. [49]

3.4.3 Surveys

Surveys, i.e. questionnaires are an effective way to get measured, opinion-based results. They are highly customable and modern online versions are easy to distribute and answer to, regardless of the device they are opened with. By putting effort into making a questionnaire, it can provide honest and precise answers. [76]

However, poorly prepared surveys can result in disqualified or, in worst case scenario, misleading outcomes. For example, if the questions are too leading, answers might be distorted. Furthermore, human aspects should be carefully taken into consideration, as personal matters, like mood, do have an effect to results. For instance, too long questionnaires tend cause frustration, that further leads to rushing through the rest of the questions. Therefore the order of the questions also matter. Other factors include amount of questions, relevancy and interests, clarity and provided type of answers. [76][77]

Likert scale is a commonly utilized type of survey, used for market research, opinion polling and governmental purposes, for example. A Likert style survey usually consists of a statement, which is to be answered by indicating agreement or disagreement. **Figure 21** shows the basic scale of answering. [78]

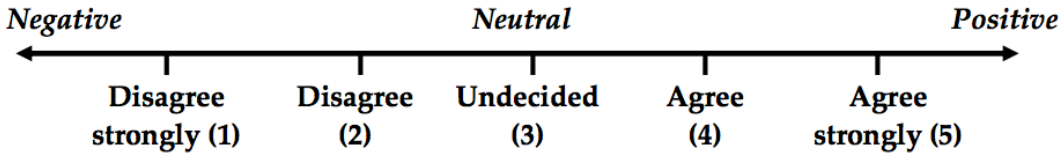

Figure 21 Common form of answer in a Likert-scale survey

An important factor in designing a survey is the amount of scale points. Research shows, that below five and above seven scale points decrease the accuracy of answers, as 2 to 4 points mostly indicate direction rather than opinion, and above seven scale points become harder to distinguish from each other. [78] Another finding indicates, that removing the midpoint, i.e. neutral point from the scale minimizes respondents'' desire to please the interviewer. However, it also points out that the amount of scale points is always up to the context of the study, therefore universal solutions do not exist. [79]

3.5 Working environments in NewSpace

Only very little research related to working environments in NewSpace – or space industry in general – exist. However, literature provides some specific requirements of technical environments, mainly related to space-eligibility. For example, contamination control is crucial regarding the success of a space mission. [8]

The cleanliness requirements apply throughout mission lifecycle: on-ground, testing, integration, launch and even on-orbit. This is extremely important since a single piece of foreign matter can have deleterious effects, like degradation of the power system, damaging optical and thermal control surfaces and even short-circuiting of electronics, which can possibly lead into damaging sensitive

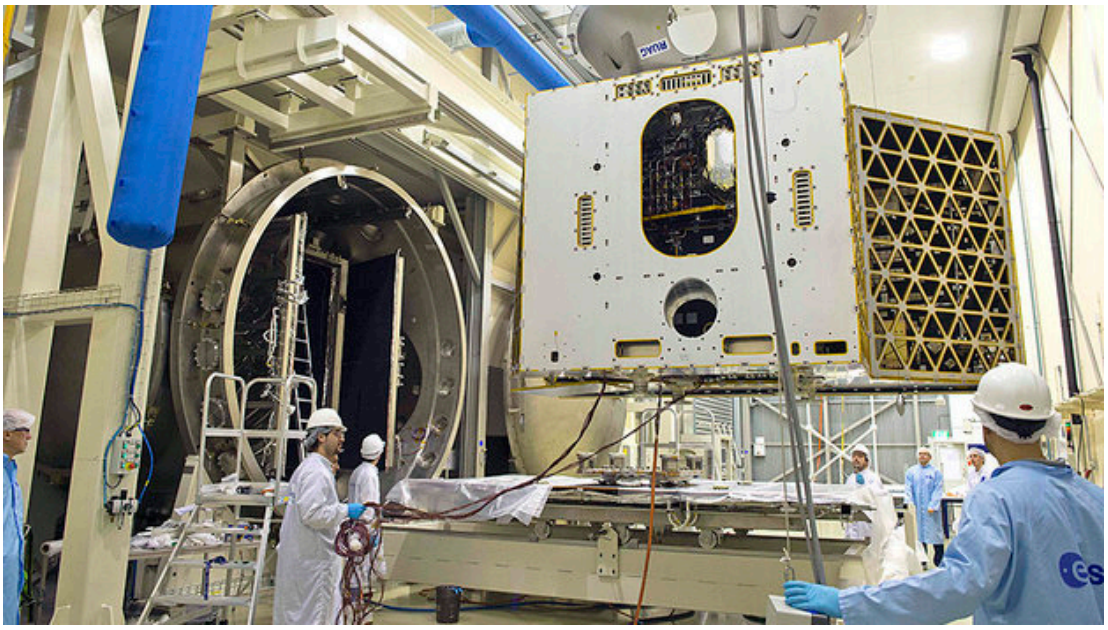

Figure 22 The largest segment of Mercury Planetary Orbiter being placed ESA's vacuum oven in their

mechanisms. Therefore, already in the very early parts of the design process, contamination control should be planned and implemented. [22][8]

The most crucial part of contamination control is on the ground: human is the biggest source of impurities. This thread can be eliminated by use of controlled facilities, like clean rooms. However, as clean rooms require heavy practises, some less controlled spaces, often called grey rooms, can be applied to simplify work steps and reduce time consumption. [8]

Space-eligibility encompasses multiple other aspects. As spacecraft are surrounded by vacuum conditions, outgassing of materials is a serious threat. The outgassed molecules can condense onto surfaces causing similar effects as previously mentioned. Therefore, vacuum chambers and heated vacuum ovens are used as part of test facilities. They vary from small ones that fit specific components to huge ones designed to have capacity for a whole spacecraft. One example of the latter one is ESA's 12-meter long and 4,5 diameter wide chamber, that can be heated up to 100°C and cooled down to -190°C. Inside the chamber, the largest segment of the Mercury Planetary Orbiter was exposed to controlled environment for continuous 23 days before it was launched for a mission to Mercury. This oven is shown in **Figure 22**. [80]

Other test facilities that imitate launch and space conditions include shock tests, anechoic chambers and radiation tests, where space equipment is being bombarded with charged particles. However, as most of the precise test equipment are very expensive, it does not make sense for a small NewSpace company to purchase all of them, especially as the testing process is only a short section compared to the whole development process. This calls for collaboration with scientific institutions, universities and other space companies. [18][8]

Some examples of office layouts can be found form traditional space industry and space agencies. **Figure 23** shows NACA's (National Advisory Committee for Aerunautics, prior to NASA) computing room in 1957 and NASA's workspace renewal in 2015. In the recent renewal, emphasis was put into flexibility and incorporation, as NASA wanted to welcome commercial actors to run simulations and actual rocket launches. However, the layout itself has not changed much

Figure 23 On the left: NACA (National Advisory Committee for Aeronautics, prior to NASA) computing office in 1957. [81] On the right: mission simulation on NASA's multi-purpose firing room layout renewal in 2015 [82]

apart from technical developments during the 60 years. The main focus is in orderliness and system control, which is understandable, as launch situations require very specific systems. However, similar design is applied on planning and development offices as well, which further indicates that NASA's interpretation of flexibility is very different from NewSpace approach. [81][82]

3.5.1 Field study: SpaceX Headquarters

To understand NewSpace working environment on a practical level, a field trip and a semi-conducted interview with an aerospace engineer was carried out in SpaceX's Headquarters in Hawthorne, California US. This field study produced multiple findings on how NewSpace methodology can be applied on a large scale. [29]

The main working area of SpaceX is an extensive open hall, where it is easy to see the current state of production at a glance. The communication between production and planning is constant and immediate by its nature, since the threshold to interact is low. In addition to transparency, emphasis is being put on flexibility. The production changes rapidly, therefore most of the tools and even complete production lines are easily moved. For example, if a 70-meter long rocket body is decided to bring in and laid on its side, other parts of production will be relocated accordingly (**Figure 24**). [29][83]

SpaceX puts a magnificent effort on product development and especially rapid testing. They are using standard parts, but also developing their own specific

Figure 24 Rocket bodies lying on the floor of SpaceX's Headquarters in Hawthorne, California US [83]

components, like screws and fittings. The aim of the customization is to optimize their spare parts regarding the volume of production, as SpaceX plans to increase their launces rapidly. Another aspect related to volumes of the parts is their plan to increasingly recycle rockets, so that one body could be used up to one hundred times. Compared to traditional one-shot missions, this is a revolutionary approach that might radically reduce the cost of access to space. By March 2017, SpaceX has successfully landed nine rockets, out of which one was reused, in other words it used the same body and rocket engine as in previous flight. [29][84]

SpaceX does most of the testing by themselves, but also outsources some of the advanced ones, like large scale shaking tests. They also test and produce their own materials in a dedicated R&D lab. For example, the lab has high-accuracy 3D-printers based on laser sintering, that enable in-house added manufacturing of space-eligible metallic parts. Research is partly being made together with universities and space agencies. [29]

Due the flexibility of physical facilities, SpaceX has developed an open-for-all change management system, that easy to follow and comment on. They have no separate task management system, which is characteristic to agile development. SpaceX has also created their own standards, which are constantly edited. As they are collaborating with NASA, they partially follow NASA's reliable standards, but on the other hand, constantly pushes for new standards to support new ways of working. This is very important as NASA is shifting towards commercial

Figure 25 The centre of SpaceX's headquarters, with a recovered Dragon Spacecraft capsule hanging from the ceiling, next to the central café [86]

launches. SpaceX was the very first private company to access International Space Station. [29]

SpaceX has been a flat organization from the beginning, and tries to keep it that way. While it's a challenge with over 6000 employees, the startup-like principles are clearly visible in everyday action. In organisational hierarchy, there are not many steps from a design engineer to Elon Musk, the CEO, who runs multiple successful companies like Tesla, Hyperloop and SolarCity and has been chosen as the most influential person in the world in 2016. [29][85]

Majority of SpaceX's methods and principles are based on trust and respect. There are no work uniforms and everyone are allowed and encouraged to express their opinions. For example, in planning meetings all ideas are welcome, regardless whether they come from an executive officer or a summer intern. In addition to ideas, also problems are handled as a great opportunity improve processes, rather than failure. Working hours are flexible, yet people are expected to put great deal of effort into work. To symbolize their values and accomplishments, the first ever successfully landed Falcon-9 rocket stands outside of the factory and a Dragon cargo capsule, that was built in the same factory in Hawthorne and flown to Earth's orbit and back, is now hanging from the ceiling in the centre of the factory. **Figure 25** shows the hanging capsule, being next to a free-for-all lunch café. Despite being a very high-tech factory, showing contrast to extreme [29]

3.5.2 Other examples of agile transitions in high-tech industry

To understand agile working environment transformation in larger context of high technology actors, two other entities were studied: IdeaSquare in CERN (European Organization for Nuclear Research) and Agile Work Oy in General Electric's Health Innovation Village. The following findings can be used as general knowledge also applicable to NewSpace industry.

IdeaSquare

CERN's IdeaSquare, which is run under the Knowledge Transfer department and located in Geneve, Switzerland, is a pilot project that aims to bring together physicists, engineers, industrial partners, early-stage researchers and cross-disciplinary teams of students to work together on R&D technologies, mainly related to CERN's particle detectors. The ultimate purpose of IdeaSquare is to co-develop new technologies and create a fruitful environment for socially and globally relevant new product ideas and innovations. In addition to field observation and discussion with multiple CERN representatives, Project Associate Harri Toivonen was interviewed. [86]

The idea, or actually a need recognition, of IdeaSquare took place in Finland. CERN's executives were on a visit in Aalto University's Design Factory and noticed that their method of bringing people together by multidisciplinary and collaborative approach was functioning well. Now, around five years later IdeaSquare is fully functioning test environment and part of Design Factory Global Network, a community consisting of 10 collaboration platfroms located around the world. [86]

Figure 26 CERN's IdeaSquare, located right next to Atlas, the biggest detector of Large Hadron Collider. [86]

Designing IdeaSquare was an iterative process. The users of the space participated to the process from the very beginning, which helped to utilize needs, generate new ideas and discover challenges. After the first environment was discovered to function well, the second one was built around a large empty hall, which was completely renovated for IdeaSquare's purposes. This enabled freedom in terms of working environment design. For example, a British double decker bus was driven from London to Geneva and turned into two meeting rooms (**Figure 26**). The hall already had a bridge crane up in the ceiling, so it was taken into use by a special way: All the rooms in the hall are built in containers, which are completely movable by using the crane and a special moving tool. The spaces function like building boxes, which basically just need to be unplugged for transformation. During the time of the interview, IdeaSquare was the version number 26. [86]

Despite being cosy and colourful, the main focus has always been around IdeaSquare's function and activities, therefore it has spaces for building things, test ideas in practise and a clean room, for example. However, the space is very different from CERN's hundreds of other buildings in many aspects (**Figure 27**). For example, physicists, many of whom are very specialized in narrow parts of science, are not used to multidisciplinary collaboration – particularly in terms of commercial activities. Nevertheless, putting importance in scientific breakthroughs and factors like openness and transparency has provided good results. An example of collaboration has been an augmented reality project, which aims to develop a tool for the maintenance workers to find correct components in ATLAS detector, located in the neighbour of IdeaSquare, but 50 meter below, in the underground. The environment by the detector is hazardous and has hundreds of thousands of components. By developing the tool, safety is increased and time for the process radically cut down. [86]

Figure 27 Traditional office room in CERN, located in the same building where World Wide Web was invented. [86]

In general, CERN aims for accurate scientific measurement, therefore effort is being put on measured outcomes of IdeaSquare. For example, the space has multiple touchscreens that have simple surveys like “How many new people have you met today?”, “How many ideas did you get today?” or “Which one is the most proactive place for you to work in IdeaSquare?”. These results are being used as indicators together with other sources of information. For instance, security cameras can be used to produce heat maps that track where people tend to spend time and where do they gather together. Another measurement factor is the coffee machine. In addition to consumption of coffee, the researchers noticed, that coffee line is among the best places where people naturally interact. Therefore the machine was modified to prepare the coffee a few seconds slower, in order to increase the probability of interaction in the share kitchen. Furthermore, a practical matter to measure is the amount of prototypes produced in workshops and courses. [86]

Just like in space industry, in CERN’s science community resistance for change appear. This was the case for IdeaSquare as well. Nevertheless, the more the community was involved in the activities around the space, the more they understood the possibilities of flexibility and openness. Now the multipurpose space is in use most of the time since it supports multiple kind of activities. A good indicator of impact it has already created in CERN, is that the amount of users has doubled during the past one year.

Agile Work Oy / GE Health Innovation Lab

Agile Work Oy is a small Helsinki-based company that focuses on working environment transformation. It recently moved to General Electric’s (GE, one of the biggest corporations in the world) Health Innovation Village, as they got a major project to provide a holistic transform for GE’s co-working space for startup

Figure 28 Warrior Café, as the first function of bringing people together in GE's Health Innovation Village [87]

companies. For this study, Agile Work Oy's CEO Esa Santamäki was interviewed in their facilities. [87]

At some point GE executives realised, that they are lagging behind in terms of innovations and general wellbeing. According to Santamäki, it also started to affect factors like recruiting and attractiveness, as young knowledge workers tend to choose welcoming companies over traditional ones. Therefore, they decided to invite fresh SME's to collaborate with their healthcare department. However, as they lacked knowledge and proper facilities, they invited Agile to help them in the transformation process. [87]

To begin the transformation, Agile planned and implemented a social hub, called Warrior Café, by tearing some walls down and combining a canteen and an unused educational space. This created interaction between GE employees, visitors and later with the startups in the Health Innovation Village. [87]

After defining the needs of both GE and the startups, a multi-purpose space for agile ways of working was designed. The space provides various environments in a flexible way, including prototyping facilities, shared meeting rooms and general get-together areas. In addition to increased interaction and well-being, this solution has dramatically decreased lead-times of new products. [87]

In general, Santamäki states that traditional companies and public entities must transform due rapid shift of global demands and competitiveness. In the future, there's simply no time for slow reaction and change resistance. As the unpredictability grows, tolerance for failure should be increased and understood as a critical part of learning process, which eventually leads to returns in the long-run. [87]

4 Case Study: Reaktor Space Lab

Reflecting to literature, Reaktor Space Lab (RSL) is a good target for a case study, as it's a spin-off from a university project, in other words an entrepreneurial actor that transformed from public-funded scientific approach to entrepreneurial actor. Furthermore, it represents the convergence of IT-sector and space industry, as it's funded and guided by Reaktor, a Finnish agile software-specialised consulting company.

This chapter investigates Reaktor Space Lab as a NewSpace company and sums up observations and practical arrangements related to its working environment, that were carried out during an 8-month period. Combining the results of observation and aspects gained from literature review (chapters 2 & 3), a survey is conducted as a practical way of measuring attributes related to working environment, as well as for evaluating the impact of changes made during the period of observation.

4.1 Spin-off from Aalto University's hands-on project: Case RSL

Reaktor Space Lab is a startup currently focusing on building nanosatellites and providing a service solutions based on Low Earth Orbit (LEO) nanosatellite data. It was founded in April 2016, i.e. only 5 months prior to this study. Before establishment of the company, many of the current employees and founders were involved in Aalto University's Aalto-1 and Aalto-2 nanosatellite projects.

RSL got its kick-off investment from Reaktor and has been largely collaborated with the company from the very begin (**Figure 30**). Currently RLS has 8 employees and 2 workers form Reaktor are developing the software side on full-time basis. RSL's main office and laboratory is located within Aalto University campus in Otaniemi, Finland. However, Reaktor provides its premises in the city

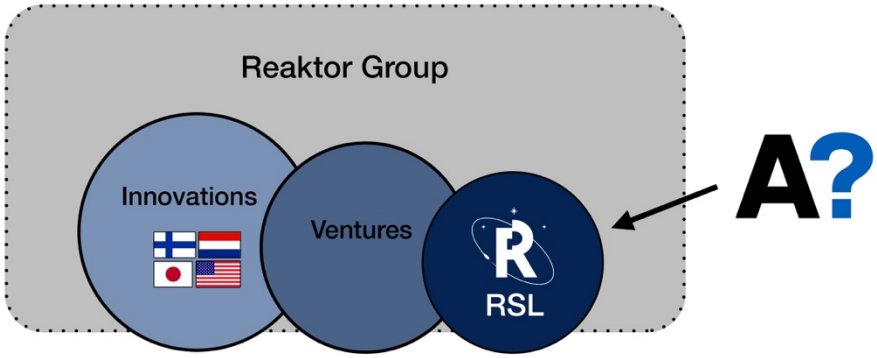

Figure 30 Illustration of Reaktor Space Lab as spin-off from Aalto University research group

centre of Helsinki for meeting purposes. There is also a functioning ground station available for satellite tracking.

4.1.1 Reaktor – An investor, mentor and co-operator

Reaktor is a creative software-oriented consultant company, that labels itself as a “strategy, design and engineering company”. It mainly provides digital solutions in an agile and human-centric way. It was established in 2000 by 10 founders, who had a goal of creating a company where they would like to work. Nowadays, Reaktor has grown to an almost 400 employee company that operates in four different countries. Reaktor has given the award of Best Place to Work in four consecutive years (2008-2011), out of which three times in Finland and once in the whole Europe. [88]

Reaktor has a unique approach to its organisational structure. The company has been referred as a pioneer of human-centeredness; its aim is to have as little hierarchy and bureaucracy as possible. Reaktor has an extraordinary employee satisfaction, yet high level performance. The company shares its operational model openly and therefore tends to not only provide products and solutions, but also create change within its customers.

4.2 Observations on RSL’s working environment

Observations Reaktor Space Lab’s working environment were made during September 2016 to April 2017. The observations were categorised according to three main components of working environment.

4.2.1 Technical environment

RSL’s physical environment covers its main office facilities and some shared resources, like kitchen and meeting rooms in the near environment. The office environment, shown in **Figure 31**, is divided into three sections according to activities:

1. Office space
2. Development laboratory
3. Leisure / meeting room

Figure 31 RSL’s new office layout in 2017

The office space provides an environment for most of the work carried out in daily operations, i.e. physical surrounding for digital work. Physically located in the same room, the development laboratory provides tools for various processes involved in the development and assembly of a nanosatellite, like soldering station, radio equipment, power supplies and basic tools varying from screwdrivers to fine electric circuit cleaning equipment.

In addition to its own and Reaktor's premises, RSL collaborates with various public entities. The company has a contract with Aalto University's Department of Electronics and Nanoengineering, which provides an access to university's facilities, including a clean room and a space laboratory for practical work, both of which are critical factors for a space tech company. Furthermore, the department has an anechoic room where radio transmission tests can be carried out in simulated space conditions.

In addition to electrical engineering and space technology, Aalto University provides spaces for practical building, testing and prototyping. Aalto Design Factory has laboratories for mechanical prototyping, including heavy machinery like CNC-milling, which are useful for mechanical testing and developing of tools, for example. Furthermore, Aalto Digital Design Laboratory (ADDlab) is specialized in advanced additive manufacturing and tools, therefore they provide an access to 3D-printers and laser-cutters, for example.

RSL also cooperates with Technical Research Centre of Finland (VTT, Valtion Tieteellinen Tutkimuskeskus), that provides service and assistance in test operations, like shock impulsion tests simulating forces during a rocket take-off, that are required by the launch provider. In addition, RSL and VTT are collaborating in research and development. VTT develops technologies that RSL can utilizes in real space conditions, which provides valuable data and experience for VTT.

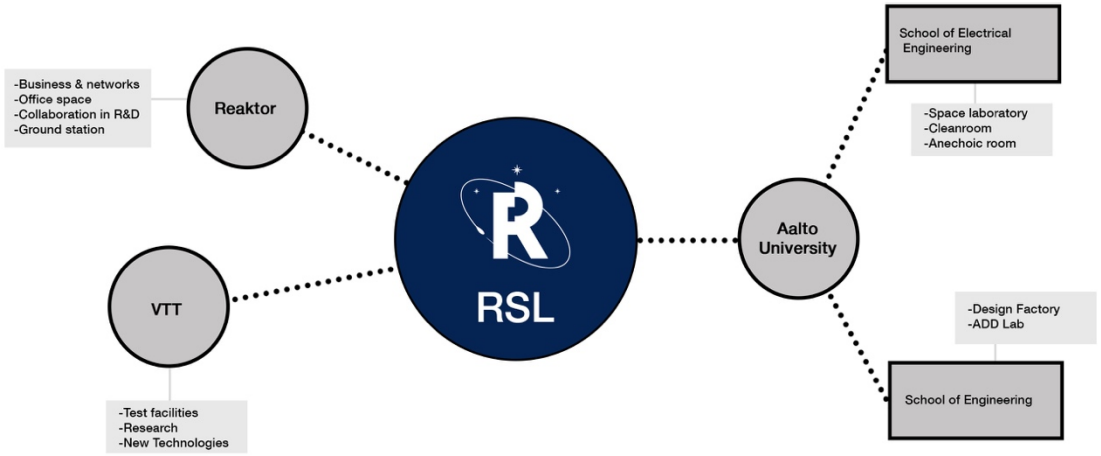

Figure 32 Reaktor Space Lab's close collaboration network

Reaktor Space Lab's workspace setting is rather typical for a young NewSpace startup. As test equipment and different space-specific facilities are expensive and often in low utilization degree, it doesn't necessarily make sense to purchase them for the company. Furthermore, collaborating with researchers tends to increase knowledge, as they have a lot of specific scientific insight. **Figure 32** shows RSL's collaboration network.

RSL's digital working environment consists of multiple desktop PC's laptops and mobile devices. As nanosatellite development mostly happens in digital world, having the right technology available is essential. For example, the compatibility of all the mechanical parts is being tested in a virtual assembly, which is further used for thermal and mechanical simulations. Decentralized software development is happening simultaneously digitally, as well as applied to physical satellite prototypes. Furthermore, electrical planning and orbit flight simulations are essential tasks to handle for a space tech company. **Figure 33** shows how digital development is combined to physical on daily basis.

Most of the internal communication happens in instant messaging application, but external stakeholders still favour phone and email. International remote meetings, though, are usually arranged using video chats. Managerial aspects, like task management, are partly happening in digital world. As documentation is aimed to be kept as minimum as possible, often just a snapshot using a camera phone is enough.

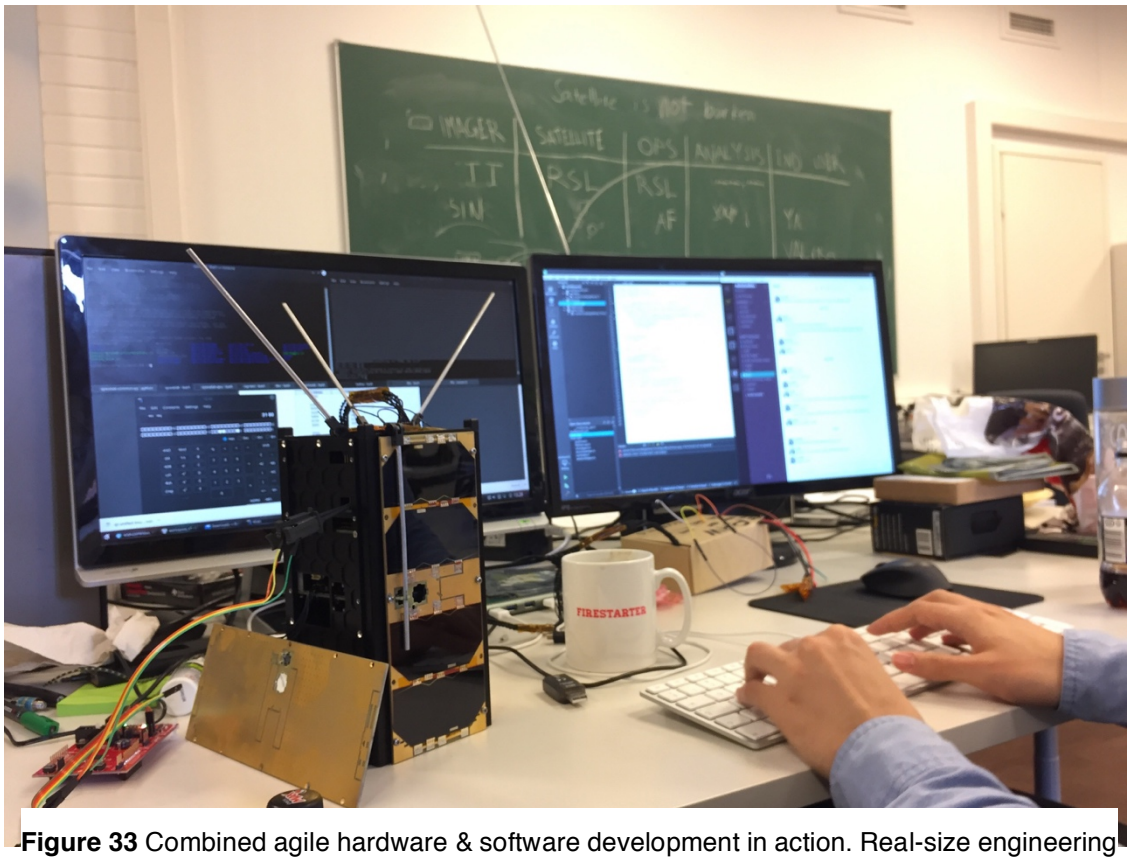

Figure 33 Combined agile hardware & software development in action. Real-size engineering model of RSL's first satellite, Hello World, in the foreground

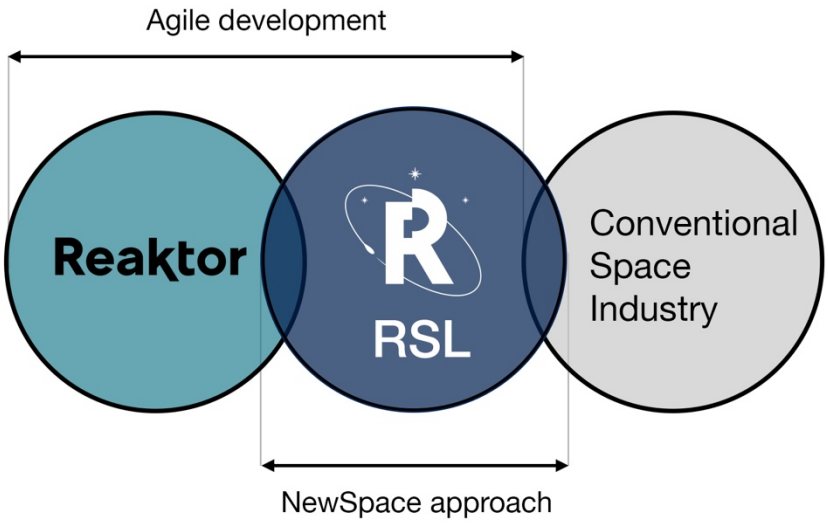

Figure 34 Reaktor Space Lab's position in-between agile (software) development and conventional space industry

4.2.2 Organisational environment

Reaktor represents a flat organisation. Until some point, employees have freedom to choose how and on what they want to work. However, importance is being put on open communication, as opinions often vary. Some tasks, like practical development of the satellite, are location depended, but employees are mainly allowed to choose where work is done. There are no working hours, but every now and then it is strongly encouraged to work during evening and night time, especially is schedules are getting tight or if there's important events, like launches happening in another time zone.

As RSL is a commercial company, all employees are involved in developing the business approach as well. It is desirable that everyone attends events and exhibitions related to field. Furthermore, especially as the company is only one year old, developers are working closely together with the board of directors, constantly thinking of new solutions that would benefit the company.

Work in Reaktor Space Lab is carried out in a very agile way, which is adopted partly from Reaktor's mode of operation, but also partly being implemented already during the student satellite projects Aalto-1 and Aalto-2, which most of the workers have somehow been involved in. As situations tend to vary, tasks are checked and discussed together on weekly basis, however employees decide their own priorities on daily basis or on-the-go. Due rapid change, these decisions are often openly explained in company's internal instant messaging chatroom, so the rest of the employees can adapt their own tasks accordingly.

RSL's agile way of developing satellites fits well to NewSpace methodology. Updates are constantly tested and prototyped, so that possible failures are being found as early as possible. Furthermore, from the beginning the testing is applied to whole system at once, very much like in agile software development. This way not only one function, but the whole system is being tested at once, covering possible compatibility issues that may cause serious surprises and backlashes in the traditional waterfall model. **Figure 34** illustrates RSL's position in-between

agile software development and space industry. From the illustration it can be seen, that one hand, NewSpace covers only part of conventional space industry, but on the other hand, that NewSpace company cannot be fully agile, as collaboration with public entities brings certain requirements.

Spacecraft development does not have to be space-eligible from the beginning. Instead, it makes sense to use standard parts early in the development, as most of those parts would not end up in flight model anyways. It's a good way to save resources, but also bring flexibility to the planning process. RSL had a good example on so called *FlatSat*, which is basically a flattened version of a satellite. It doesn't resemble an actual satellite and it is definitely not space-eligible, but it helps in the development stage and allows fast changes to be made on-the-go. Despite looking a bit unprofessional, RSL's first FlatSat was made of cardboard, which indicates that functionality and methods come over external pressure.

Reaktor Space Lab is currently focusing on two main tracks in their business perspectives. First track is commercial one, where they are constantly looking for possible needs to be filled utilising nanosatellite data. The other one is more scientific, in other words collaboration with the public sector. These two tracks bring very different approaches to activities and way of organising. While the scientific one is based on technical requirements and capabilities, the commercial one requires constant concept development, marketing and market research.

4.2.3 Human environment

Reaktor Space Lab has given employees general roles, or field of responsibilities. However, these roles are only approximate and does not limit tasks. Vice versa, learning, enthusiasm and exploring new fields is encouraged.

The general roles "on the paper" are currently following

- CEO (chief executive officer)
- COO (chief operating officer)
- CTO (chief technology officer)
- System engineer
- Electrical engineer
- Software engineer
- Mechanical planner
- Product designer

Furthermore, two additional software developers from Reaktor are working on the satellite and ground station software. Despite the distance between Reaktor's office in Helsinki and RSL's office in Espoo, close collaboration is preferred.

The average age in RSL is between 30 and 35. For a space company, that is considerably young, which affects attitudes ways of working. For example, most of the workers consider themselves as digital natives, therefore there is a genuine interest in adopting new technologies.

The flow of information in RSL is very natural and casual, sometimes leading into loud shared discussion. In general, this is accepted, although from time to time distractive. Work and free time are mixed together, especially as most of the

workers have the instant messaging platform installed on their mobile devices. However, this gives also flexibility in terms of location and scheduling. For example, during the study period, a few workers travelled periods of one to two weeks, still being able to contribute to development and discussion.

4.3 Development during observation period

Reaktor Space Lab's working environment faced several changes during the observation period. To begin with, the office was located in the same space as Aalto student satellites were developed. **Figure 35** shows the first layout, which had two separate rooms, out of which the bigger one held developers, meeting table and daily activities, while the smaller one was occupied by the CEO and COO.

The first change in the space was a re-arrangement; as a result, all workers were transferred to same space. Furthermore, desks and chairs were re-arranged so that the small room became a quiet room for individual work, prioritised for video and phone calls, which required privacy. However, as complete relocation was coming ahead, no purchases for the quiet room were made, therefore it reminded mostly empty as employees preferred staying in the bigger room, despite of occasional noise.

During the re-arrangement, personal preferences were asked and needs observed. For the practical part, i.e. moving furniture, everyone in the office participated and also made choices along the process. As participatory aspects of working environment were a research topic of this study, this wasn't highlighted but rather included in the process as a natural part of creating something together.

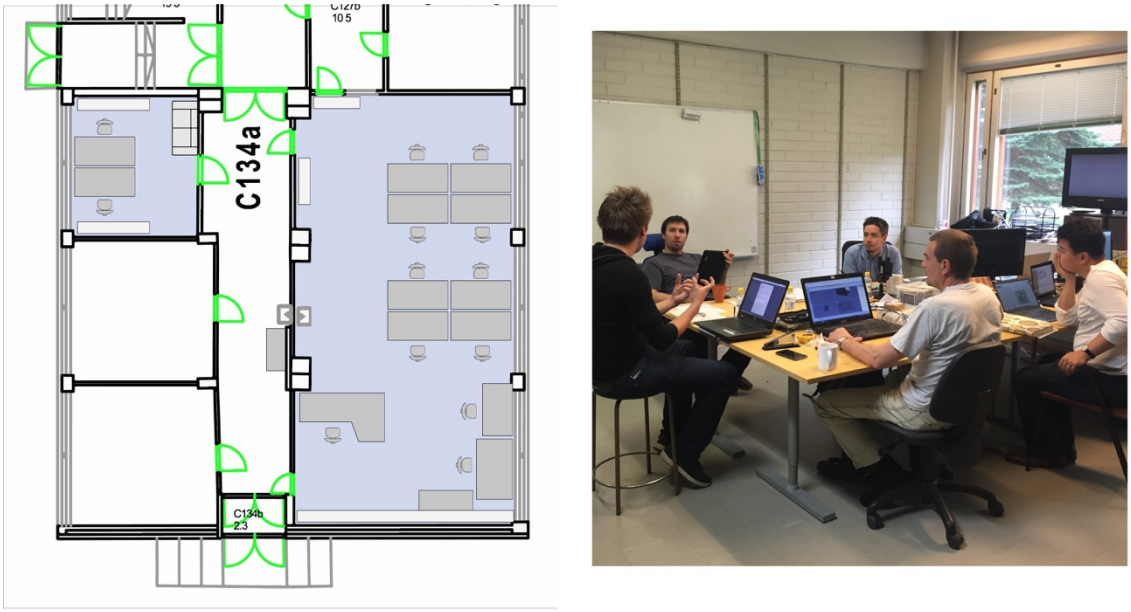

Figure 35 Reaktor Space Lab's floor plan and a meeting setting in the beginning of the study (September 2016)

Another visible symbol of change was a pool table, that arrived in the office after the first month of this study. In addition to leisure and enjoyment, the effect on proximity was researched on. In a physical sense, it immediately affected to proximity, as it took significant amount of space in the office.

The biggest change in the working environment took place in February 2017, when RSL's office moved to a different location (**Figure 31**). The new office is still located in the same building, in university campus, but in a renovated wing. During the relocation, RSL invested in lab equipment and tools. A new designated area for building and storing satellites and prototypes was established, including specific tools for satellite development, like power sources, oscilloscopes and a soldering station. On the other hand, Aalto's previous space laboratory was moved to different building, so access to the lab became limited. The office layout can be seen in **Figure 36**.

Emphasis was put into well-being and visual aspects, as more external visitors was estimated to visit the lab during funding rounds. New furniture was acquired, and a specific room was designated for relaxed meetings and quiet work. Artefacts that symbolise the culture, like a retro Amiga gaming console and movie-themed posters were brought in the office. This approach turned out to be useful as multiple interviews and video shootings by media were made in the space during the time Aalto-2, Finland's first satellite was launched into orbit. Artefacts that symbolise the culture, like an old Amiga gaming console and movie-based

In addition, visualisation of information was tested and studied on. In addition to traditional blackboards that existed already in the space, more whiteboards were purchased for thought visualisation and team work. One of them was turned into a Kanban-board, that made progress and tasks visual (**Figure 36**). The tasks, posted on the board with post-it notes, were typically discussed together at least once a week. Furthermore, components, tools and equipment were labelled as an attempt to raise productivity.

New cleanroom was implemented in a room next to the office space right after the end of this study. This is expected to have a major impact as satellites and their subcomponents can be built and tested in a controlled room.

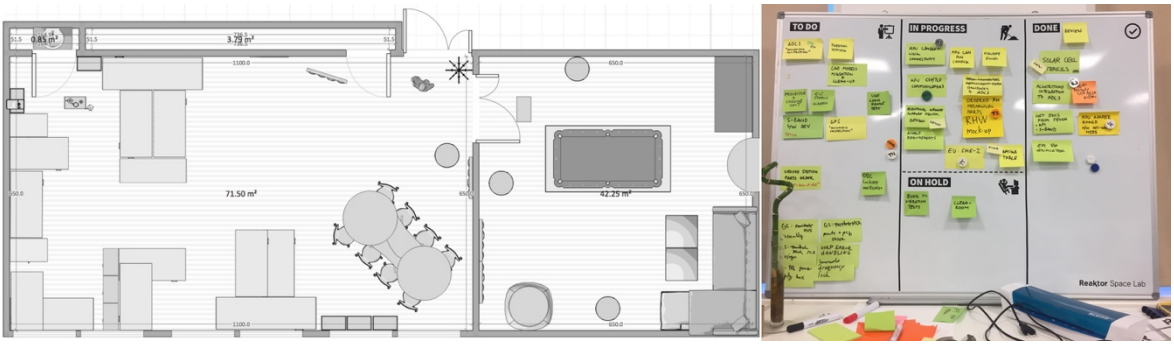

Figure 36 Plan of the new floor layout and a Kanban board for task visualisation

5 Survey of Reaktor Space Lab

5.1 The process of designing applicable survey questions

For measuring the state of Reaktor Space Lab's working environment and its development, an online survey was conducted. This approach was estimated to be most suitable way to measure opinions and to get comparable numbers.

One of the most important matters, when designing a survey, is to know *what* is being measured. Therefore, desirable aspects were adopted from literature (chapters 2 and 3). These desirables were turned into bold statements, supported by the literature as well. Using these biased statements, neutral survey questions were formulated, categorised and chosen according to relevancy in RSL's working environment. The statements and questions can be seen on **Table 7**.

Before an online survey was created, the questions went through inspection focusing on common flaws in questionnaires. For example, double barrelled questions, which have multiple aspects included in one question, tend to cause both difficulties for the survey attendees, as well as for the survey interpreters. Questions identified as double barrelled were either reformed or removed.

Furthermore, effort was put into quality and relevance, using basic indicative questions as a reminder: 1) Are we measuring the right thing? and 2) Is the measurement precise enough? For the sake of clarity, any misunderstandings were carefully thought and, if necessary, further explained in the survey. The style of the questions was kept as practical as possible, and photos and illustrations were used to explain situations.

After choosing and categorizing the questions, three main sections were conducted. The first section was designated to measure firstly the current state of RSL's working environment, and secondly the state of the environment in the beginning of the study. Comparing these two sets of results, the direction of the development could be calculated. For the style of answer, a 7-step Likert-style scale was chosen due it's docility: a designated scale indicator label can be added individually for each question, which provides clarity for the survey attendee. A middle point (number 4 on the 7-unit scale) was provided, since all the questions were not fully related to all workers. Therefore, having a neutral choice leads to more precise results. Between 5 and 7 points, the latter was chosen, as it indicates slight changes better in comparison – 5 point scale only has one step in between neutral and extreme ends. Furthermore, including a neutral point is a way to justify necessity to answer the questions, which was applied in this survey.

The second section was designed to provide quantitative data, as scaled opinions are very personal. These questions are mostly aimed to general factors in everyday activities. Before the survey, matters like share of time being spent in digital workspace, were only educated guesses.

The third section consists of Likert-style statements, that measure general opinions of the current state of the company, as well as ways of working. The 7-point scale from first section was applied to this part due sake of clarity for the attendee. Third section was followed by a optional general feedback form.

Table 7 Bold statements and survey questions related to them

Field	Bold statement	Question	
Working styles, acoustics	*"An efficient workplace has multiple spaces for different purposes, like quiet work, building & prototyping, communication"*	Does the workspace support different kind of working styles? (For example: quiet work, team work and online meetings)	Section 1: Comparison
Working methods	*"Right tools enable employees to focus on testing their ideas and actual working"*	Does the working environment have the right tools for you to achieve your working goals?	
Open space, communication	*"Open office supports immediate communication"*	Does Reaktor Space Lab's working environment support immediate communication? (For example: no need to postpone emails)	
Flexibility	*"Flexible spaces support the attitude towards change and alternative ideas"*	Do you feel that the working space is flexible for change? (Is it easy to modify the space according to variable needs?)	
Efficiency	*"Having the right tools available encourages to immediate action"*	Does the working environment encourage for immediate action?	
Interaction	*"Informal interactions won't flourish if people can't avoid interacting when they wish to"*	Do you feel that you can avoid interacting with other people when you don't want to?	
Quality	*"Constant testing is essential for a good outcomes"*	Does the space support constant testing?	
Cleanliness, order	*"A space company has to fulfil a proper amount of cleanliness to ensure the quality"*	How easy it is to maintain a required overall cleanliness of the workspace? (In this case, 'cleanliness' includes order of tools & materials and hygiene aspects, for example. 'Required' refers to necessary level in order to achieve proper quality of work and overall pleasantness)	
Creativity, joy	*"Optimizing the right level (tolerance) of playfulness drives innovation – Having proper amount of fun while working increases creativity and therefore productivity"*	Does the working environment encourage you to have fun during the work day?	
Seriousness, credibility	*"A NewSpace company has to find a balance between agile working and serious space tech"*	Do you feel confident about the credibility of your work? (For example: The collaborating institutions, like ESA and Tekes approve the operations and the final outcomes are space-proof.)	
Organization	*"Flat hierarchy fits into NewSpace product development by increasing freedom and responsibilities and helping communications"*	How hierarchical does the working environment feel like? (Example of hierarchic organization: top-down management, threshold on communication, inequality)	
Informal interaction	*"Informal interaction creates stronger ties between people, which increases the commitment to work"*	Does the working environment feel inviting for staying after hours?	
Personal needs	*"An efficient working environment supports individual needs"*	How well does the working environment meet your personal needs? (For example: comfort, concentration, intimacy)	
Involvement (co-design)	*"It is important to include the whole working community to design a suitable work space according to various needs"*	Do you feel you have been involved in the office space implementation? (Including planning, realisation and improvements)	
Business	*"For a NewSpace company the space has to support business-perspectives, like meetings"*	Does the working environment support the business point-of-view, like meetings & visitors, marketing and credibility?	
Visual appearance	*"A visually appealing and differing space can be seen as a symbolic manifestation of doing things differently"*	Is the visual look of the workspace in line with Reaktor Space Lab's way of working?	
Efficiency, risk	*"Learning by doing is less time consuming and more sufficient way to find out failures than theoretical approach"*	During the past 5 working days, how many times have you tested your ideas in practise? (Physical or digital world)	Section 2: Quantitative
Digital workspace	*"Information overflow affects negatively to results"*	How many times have you been interrupted by Slack messages during the past 5 working days?	
Physical workspace, acoustics	*"Open office affects negatively to simultaneous ongoing working methods"*	On an average working day, how many times does your work get interrupted by other workers and/or their working methods?	
IT	*"Most of the modern space tech development happens in digital World"*	How much of your working time would you estimate of spending in digital workspace? (Computer, slack etc.)	
Working balance	*"For efficient work, one needs to have breaks from thinking"*	On average, how many breaks (involving non-work-related activities) do you have during a working day?	
Documentation	*"NewSpace companies are trying to document as little and as efficient as possible for meaningful outcomes"*	Does the digital workspace support easy documentation?	Section 3: Likert
Visualisation, common understanding	*"Visualisation of information brings employees on the same page"*	Does the working environment support visualisation of your thoughts? (Visualisation can be related to ideas, thoughts and tasks, for example)	
Tech	*"The adaptation and use of new technologies increases flexibility and efficiency"*	Does the working environment support adaptation of new technologies?	
Location	*"For a NewSpace company, the location or workplace matters"*	What is your overall opinion about Otaniemi as a location? (Regard for example commuting, collaboration with other companies and institutes, personal interests)	
Passion, creativity	*"Combination of passion and connecting experiences in a new way drives creativity"*	Do you feel passionate about working in the Reaktor Space Lab's facilities?	
Meaningfullness	*"A modern company has a defined purpose on a larger (societal) scale"*	How clear is the purpose of Reaktor Space Lab to you?	

One critical factor that might negatively affect survey results is the time used for answering. If it takes too long, the attendee gets tired in the end and does not pay as much attention as in the first section. Therefore, 10-15 minutes was chosen for the scale of answering time. To help with the estimation, the survey was once gone through by the maker. This answering time was clearly communicated to all the attendees in invitation, as well as in the beginning of the survey.

There are plenty of online surveys available, ranging from simple free ones to very effective ones, some of which even provide consulting. After benchmarking different options, Typeform.com was chosen, as it focuses on simple design, superior compatibility with different kind of devices and comprehensive analytics tools. Another benefit of its design is that it encourages the attendee to answer and focus to only one question at a time. The simplicity and compatibility of the survey was well communicated in the invitation, so that attendees wouldn't feel frustrated to sacrifice precious time on the survey – according to feedback all the RSL employees have experienced poorly made questionnaires. The full survey can be found in **Appendix A: Online Survey**.

5.2 Analysis and limitations of methods

Reaktor Space Lab is a small company which means that the results are very limited and case-specific, and therefore not scalable in general. Furthermore, employees know each other very well, which tends to affect the answers. To prevent flattering and other distortions, effort was put into full anonymity. On this account, the attendees were not asked their age, time spent in the company or any other trackable details. However, for possible further interpretations, they were asked to provide a random set of strings (including letters and numbers). This turned out to be somehow trackable with some personas, despite highlighting the aspect of non-traceability in the survey.

Another limiting aspect is the dependency on the stage of the ongoing project. As the agile ways of developing a satellite changes the situation on daily basis, some questions, especially the qualitative ones were not relevant or would not provide comparable data.

While multi-choice questions are fast to answer to and provide relatively good numbers, plenty of information is being left out, compared to an interview, for example. Dues this matter, further discussion with attendees took place after the survey.

As human memory is limited, more precise results from the previous working environment would have gotten by conducting another survey already in the beginning of study. To refresh the memory, photos and brief descriptions of the old office were provided in the survey. It is challenging to state whether this affected the results, as the main goal of the survey was determine current situation and compare it to previous one, instead of measuring the ultimate state according to previous understanding of the attendees.

5.3 Survey results

Altogether seven individuals participated in the survey, in other words all the representatives of Reaktor Space Lab at the time. That makes the participation rate 100%, which was expected before.

Average time to complete was 15 minutes and 39 seconds, which was slightly above the planned 10–15 minutes. However, one participant stayed on the page around one hour, which clearly raised the average time. Excluding that response, the average time to complete fit the planned range. Therefore, it can be supposed, that the time that it took to answer didn't alter the results significantly.

5.3.1 Results of Section 1: Comparison

Figure 37 shows the average results of the first section, that compared the current working environment to the previous one. The average was calculated using simple arithmetic mean formula, as the sample, i.e. amount of answers was only seven.

With '1' being the lowest level of acceptance and '7' being the highest, it can be noticed, that all desirables, except one, got improved during the period of study. Moreover, the one that decreased was hierarchy, which in reality was an undesired attribute. As a conclusion, all the matters are above neutral, which is a clear signal that RSL's working environment is shifting towards right direction. The most substantial matters will be further discussed below. Larger version of the diagram shown in **Figure 37** can be found in Appenix B.

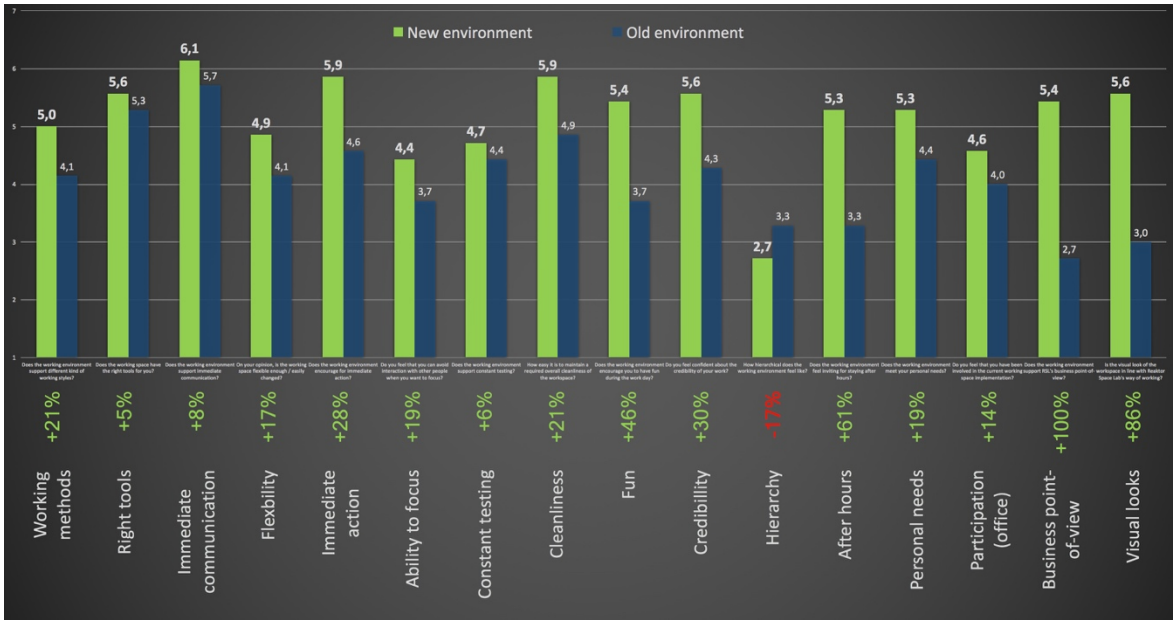

Figure 37 Average results of the comparison part of survey indicating the direction of change [Appendix B]

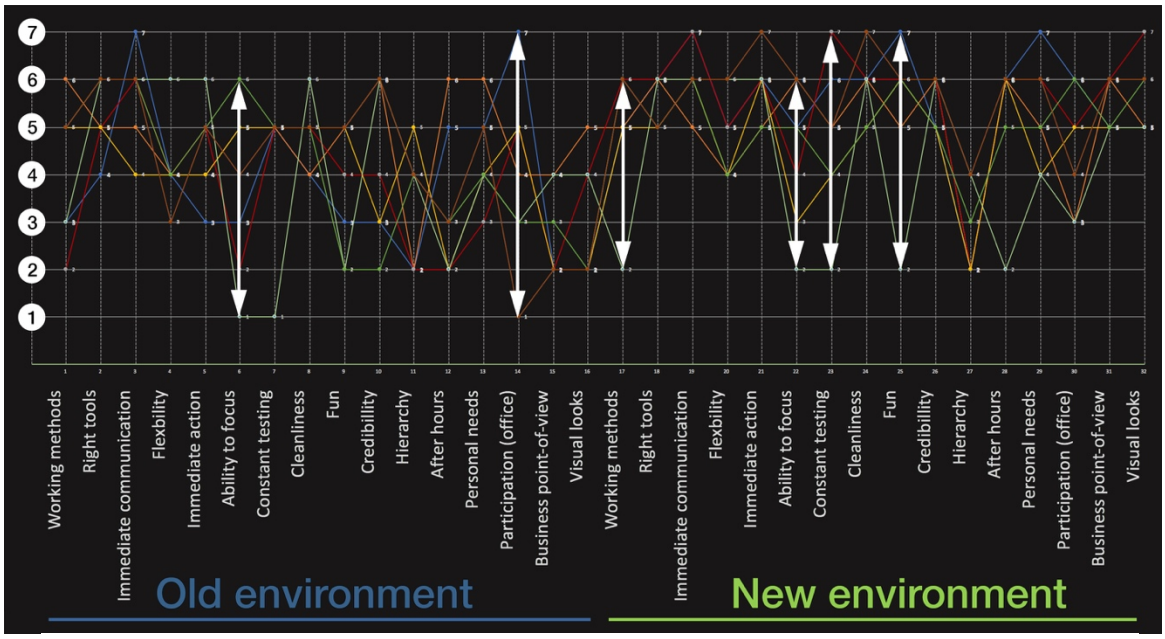

Figure 38 Dispersion of answers in working environment comparison [Appendix C]

One notable aspect of the first section was dispersion of the answers. Despite the results being satisfactory, some answers varied a lot in the scale of negative to positive. **Figure 38** shows the dispersion, out of which most remarkable ones are highlighted with white arrows.

The most radical change occurred in the business perspective, in which the question was: “Does the working environment support RSL’s business point-of-view? (For example: marketing, meetings & visitors and overall credibility)”. The reason for this result is quite simple: according to further discussion, the employees did not feel like bringing visitors to the previous space, as the visual looks and feeling of credibility were misleading. While this matter does not necessarily correlate to the outcome, in other words success of a mission, it certainly weakens the commercial aspect, which is remarkably important for NewSpace.

While the visual looks, that increased by remarkable 86% in relation to “Reaktor Space Lab’s way of working”, might not directly correlate to the success of the mission, confidence and space-eligibility does. It is worth noting that the 30% rise in credibility indicates strong improvement. The particular question was: “Do you feel confident about the credibility of your work? (For example: The collaborating institutions, like ESA and TEKES approve your operations and methods, and the final outcomes will be space-proof)”. Another aspect relating to success-rate would be cleanliness; the ease of keeping the working environment clean raised by 21%.

The ways of working were also improved on multiple levels. Despite losing the access to Aalto’s lab and tools, the new environment proved to support working methods by 21%. Furthermore, immediate action, an important factor for agile working methods, increased by 28%. While open office style tends to get noisy, the ability to focus actually improved by 19%. This is partly due filling personal needs (+19%).

In spite of filling needs, opinions vary, which can be clearly seen in **Figure 38**. From the previously mentioned, ability to focus divided most opinions, both with previous and current working environment arrangements. A decreasing matter was, that one person was working for Aalto, and had his own room in proximity of the previous office. On the other hand, an increasing factor was that due concentration issues, high quality active noise cancelling headphones got ordered for one person. This topic also got an interesting mention in the open feedback section – one attendee indicated, that according to his own words “he likes to be interrupted”.

One thing was clear: The new environment encourages to enjoy work and leisure. Fun, often seen as an important component of innovation and even trust, increased by 46%. The new environment strongly encouraged to stay after hours (+61%), which further leads to informal activities, an important indicator of non-hierarchic environment – which seems to be correct, as hierarchy decreased by 17%.

Two factors that should be taken better into consideration, are constant testing (+6%), and participation in working environment development (14%). The latter one is important regarding proximity, which is especially important regarding the results in small startup activities.

5.3.2 Results of Section 2: Quantitative questions

Section 2 measured quantitative matters. The first question measured was: “During the past 5 working days, how many times have you tested your ideas in practise?”. This question is related to both immediate action and ideation. The average answer was 6,3 times. However, two of the respondents answered “more than 15 times”, while one person haven’t tested *any* ideas during the past five days. There’s clear differentiation in the aspect of testing.

The second question measured distraction by question: “During the past 3 working days, how many times have you been interrupted from your ongoing task by Slack messages?”. While it was pre-assumed, that instant messaging distracts from actual work tasks, on average just above one message per day was seen as distraction. Not a single respondent had been distracted more, than ten times during the past three days.

However, other kinds of distraction seem to be more dominant in average working day at RSL’s office. The question “On an average working day at RSL's office, how many times does your work get interrupted by other workers and/or their working methods?” revealed, that on average employees are interrupted 6 times on daily basis. While it does not seem to be a major issue, first sections “ability to focus” question, with an average score of 4,4 out of seven, with 4 being neutral, indicates that there’s room for improvement.

The forth question revealed, that RSL workers spent 75% of their working time in digital workspace. Assuming, that it’s needed to get the work done, it suggests putting priority in improvements of digital working environment.

The last question of the second section was estimating the amount of breaks per working day. The average result, 3,4 times, equals roughly to lunch and two

coffee breaks. However, there's also personal variation, as some two of the workers keep only one break, while two others have up to 6 daily breaks. It should be noted, that the question didn't take a stand on the length of the working day.

5.3.3 Results of Section 3: Likert-style statements

Figure 39 shows the results of third section, which measured opinion using Likert-style statements. Like in first section, the average was on the positive side for all of the questions. The most disagreed statement was related to documentation for external stakeholders (score: 4,1), indicating mostly to public entities, like space agencies. In contrast, documentation for internal purposes got an average score of 5,3.

Most opinion-dividing matter was ease of visualisation – while two respondents gave second highest answer, one person stringy disagreed giving it the worst possible score. Technology adaptation was safely on the positive side (4,6). As location matters in NewSpace industry, it was good news that all of the respondents approve current location.

Good news was, that all RSL employees feel passionate about working in current working environment; especially two of them, who strongly agreed. Also the goals of the company, among with purpose, seem to clear very clear to employees, scoring an average of 6,1/7.

Figure 39 Results of section 3: Likert statements; colourful lines represent individual respondents and the black one shows the average result

The voluntarily open feedback question got four answers, out of which the one regarding acceptance for interruptions was already mentioned before. In contrast, one concern about the noise in shared office was raised up, highlighting the different personal preferences. The last two comments included positive feedback about the survey and working environment in general. In addition, willingness to discuss these topics together was raised.

6 Discussion and suggestions

6.1 Key findings from the background study

In the beginning of the study, the main focus of the scope was in physical working space and technical needs of NewSpace methodology. However, the topic was soon found to be limited, as developing environment only on physical aspect does solely support technical aspects. As NewSpace as itself is a multidimensional concept, it should be approached multidisciplinary.

The change from workspace to working environment changed broadly the content of this study, therefore goals were also changed. Including human and organisational aspect increased complexity, yet it led into a much more extensive learnings and outcomes. Naturally, due this decision, technical aspects were studied and discussed with less details. Nevertheless, in general, shifting from technical perspectives towards human needs is a common phenomenon in NewSpace. This was often seen for example in space conferences, where dichotomy between traditional space industry and NewSpace was occasionally particularly steep.

As the topic of NewSpace is relatively new, existing research and literature was limited. However, throughout the 8-month study multiple new journal articles were published and remarkable news related to NewSpace appeared in media on weekly basis. Exponentially increasing amount of publications indicated the novelty and hype around the field.

Literature focusing on both NewSpace industry and working environment is virtually non-existing. More research related to NewSpace working environments should and probably will be carried out if the trend follows general predictions, i.e. NewSpace sector will continue its exponential growth. As a metaphor, similar leap happened when IT-sector emerged.

Most of the literature on NewSpace seems to focus on praising its revolutionary way of changing space industry. However, what's mostly being left aside, is the fact that NewSpace methodology, as such, does neither apply to all space industry, nor provide universal solutions to existing challenges in space industry. As a relatively new phenomenon, only limited real-life examples exist. Therefore, it lacks versatile literature and research.

What both Toivonen at CERN and Santamäki at Agile Work highlighted during the interviews, is that bringing together people with different background is a main source of innovation. In general, this seems to be one of the current element in working environment design and a starting point for transformation. Therefore, instead of confrontation, where privatization of space industry might easily lead to, emphasis should be put on cooperation. Weaknesses and strengths from both aspects should be studied, clarified and acknowledged to build basis for sustainable collaboration, that can help space industry – and human kind – to take the next big leaps in exploration of the universe.

6.2 Key findings from the case study

In general, to create intended change, it needs to be addressed first. In Reaktor Space Lab's case, raising discussion and creating visible impact were key elements to encage people to rethink their environment. It seems to be quite often the case, that employees and especially the management are too busy with their everyday activities to pay attention to such seemingly secondary matters, as working environment. However, there's multiple examples that show how workplace transformations can yield dramatic benefits for the company, as well as employees.

As the scale of the study in Reaktor Space Lab was modest, it cannot be scaled up or implemented to other cases on as such. Nevertheless, working environments, along with work culture, are always case-specific and cannot be propagated. The case study was a good example on that aspect as well – despite Reaktor being a forerunner in modern working environments and showing a close example for RSL, the culture does not spread comprehensively without effort.

Various matters eased inspecting and testing of RSL's working environment. In addition to the previously mentioned constant influence of Reaktor's way of working, RSL employees seem to have an approving attitude towards change in general. This might be partly due the relatively young average age of the company, but also because of their agile ways of working since the very beginning of the company. Creating change in traditional corporations, including the ones related to space industry, remains a challenge.

Being able to prove the positive – or any kind of – effect is crucial in transitions. This case study revealed the importance of finding right ways to measure abstract matters. Without conducting the survey, this study and its findings would have remained very plain. Furthermore, after filling in the survey, RSL's employees seemed to be more interested in the topic in general.

Participation is another key element of a successful change. In best case scenario, working environment is fully co-created, encaging people to maintain and constantly improve it virtually effortlessly.

6.3 Suggestions

For the Reaktor Space Lab, it is strongly suggested to look into the numbers of the survey and put extra focus on the parts that got a low average score or high dispersion. For example, ability to focus, which scored relatively the lowest score in the first section of the survey, requires extra attention. There are plenty of ways to improve this matter, ranging from rearrangements and purchasing of noise-insulated spaces to expanding office outside of the current space, for instance. Investing on productivity saves other resources and leads to better outcome. Mobility should be taken into consideration, as most of the workers use laptops as their main digital tool.

Another matter to pay attention to is improving visualisation and practical testing of ideas. Building mock-ups and prototypes tend to bring people together and help them to share common understanding of the situation. Simple way to start

would be getting basic tools and some bulk materials and designating a space for storing them.

A low-cost approach to change the situation is to come up with set of principles guiding every-day activities. Rather than creating limiting rules, emphasis should be put into common benefits and understanding. Flexibility and testing what works are key ways to develop principles.

For possible growth in the future, flexibility to working environment in general should be taken into consideration. With more people, there's even a bigger need for customized space for different activities, according to varying situations. Redesigning of the environment should always start with defining needs.

Systems for maintaining and developing a suitable working environment should be implied. Participation is a good starting point, therefore workshops and informal get-togethers are highly suggested. As fundamental issues do not seem to be brought up on daily discussion, another suitable solution would be creating an easy feedback system, that could be kept anonymous, if it helps for getting honest opinions and discovering true needs.

10 steps towards better environment – General suggestions for redesigning working environments

As a suggestion for any company aiming to change its working environment, following step-by-step list was prepared. While the focus was in NewSpace companies, it is rather universal. NewSpace aspects should be implemented in sub-sections.

The order of the following steps is only a preliminary suggestion. It should be noted, that creating, maintaining and developing a desirable working environment is an iterative process. Multiple aspects are included in working environment design, but not all of them need to be conducted at once.

1. **UNDERSTAND**
    - Key elements: What does a working environment consist of?
    - External elements: What are the trends and forces driving your working environment?
    - On a general level, estimate the current state of your company, using technical, social and organisational aspects.
    - Benchmark: using successful examples helps you and your colleagues to understand the impact and purpose.

2. **DEFINE**
    - What are the very basic needs for your company to run (NewSpace) business?
    - What "extra's" does your company already have in addition to previous needs?
    - Desirables: What is the direction the company should go to?

3. **INVOLVE**
    - Latest now, as you have the basic understanding and goals, involve your working community to the process
    - Explain: Win the colleagues over by clarifying why working environments matter – using previously found benchmarks helps

4. **MEASURE**
    - What is the current state of your company? Numbers are often needed for credibility – use existing methods

5. **IDEATE**
    - Start creating ideas – however, remember to include stakeholders and make sure that the ideation process is open enough; in ideation, quantity comes over quality & far-out ideas should be praised
    - Select the best ideas, for example according to potency, popularity and feasibility
    - Further develop the ideas

6. **PLAN & DESIGN**
    - Based on your ideas, create a design
    - Create a project plan
    - Estimate the costs of the project

7. **TEST**
    - Start with small, involve co-workers
    - Keep it flexible

8. **IMPLEMENT**
    - Carry out the actual implementation process, however keep on discovering new ideas

9. **EVALUATE**
    - Discuss: Keep the communication as open and as relaxed as possible.
    - Observe: How does the environment work in reality?
    - Measure: What are the results compared to previous state?

10. **DEVELOP**
    - What went well?
    - What could be better?
    - Make sure that the development is continuous!

7 Conclusion

This research focused on working environments supporting ways of working, that are charasteristic for NewSpace companies, i.e. commercial actors in space industy. Compared to traditional space industry palyers, which seldom take modern working environment into consideration, these companies have specific needs, which were defined in the second chapter using literature and case examples.

Working environments, on the other hand, consist of three main components: technical, organisational and social environments. This should be understood and comprehensively taken into account in designing working environments, as the key is to find a balance between these tree aspects. Working environments of the future answer to specific needs and trends, which were addressed in the third section of the study. Using a the previously defined needs and these desirables, a framework for designing work environments suitable for NewSpace companies was drawn up.

These matters were researched and partly tested in practise in Reaktor Space Lab, the case company of this study. For measuring the impact, a survey was conducted. Results of the survey indicate, that comprehensive working environment design does have an impact in a NewSpace company. However, as the results were limited, no extensice conclusions could be drawn. Furthermore, the study revealed that NewSpace approach does not apply to all space industry, therefore working environment design for NewSpace companies as such does not apply to traditional space industry.

Using these findings, some general suggestions, as well as practical suggestions for Reaktor Space Lab were provided.

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9 Appendices

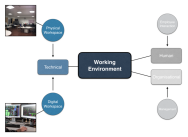
Appendix A: Online survey

Appendix B: Survey Section 1 results

Appendix C: Survey Section 1 dispersion

Appendix A: Online survey

1 Section 1 | Introduction to the topic and terms



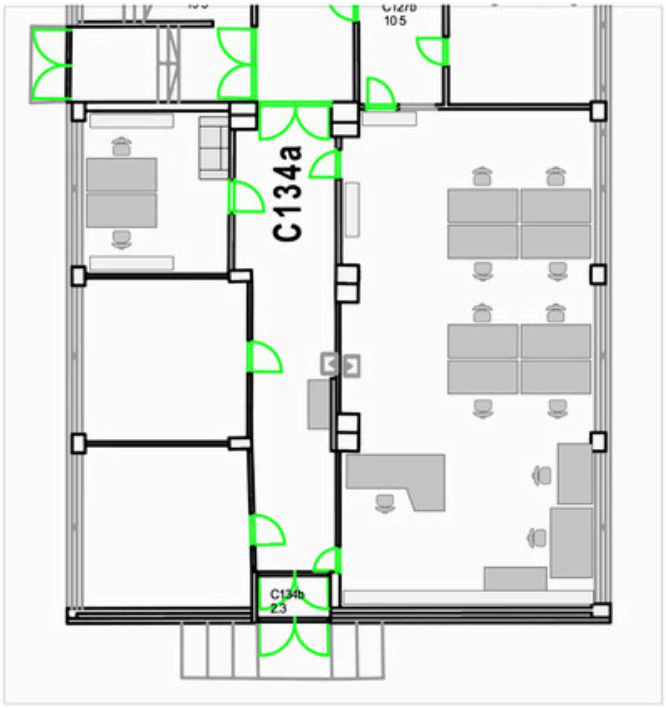
This survey is evaluating the characteristics of our working environment and estimating the difference between the previous and current facilities.

In this case, the term *working environment* refers to the combination of physical and digital workspace, as well as interaction between employees and organisational structures. The main focus of this study is in the technical aspects:

The *previous working environment* refers to the setting in the beginning of this study (September 2016):

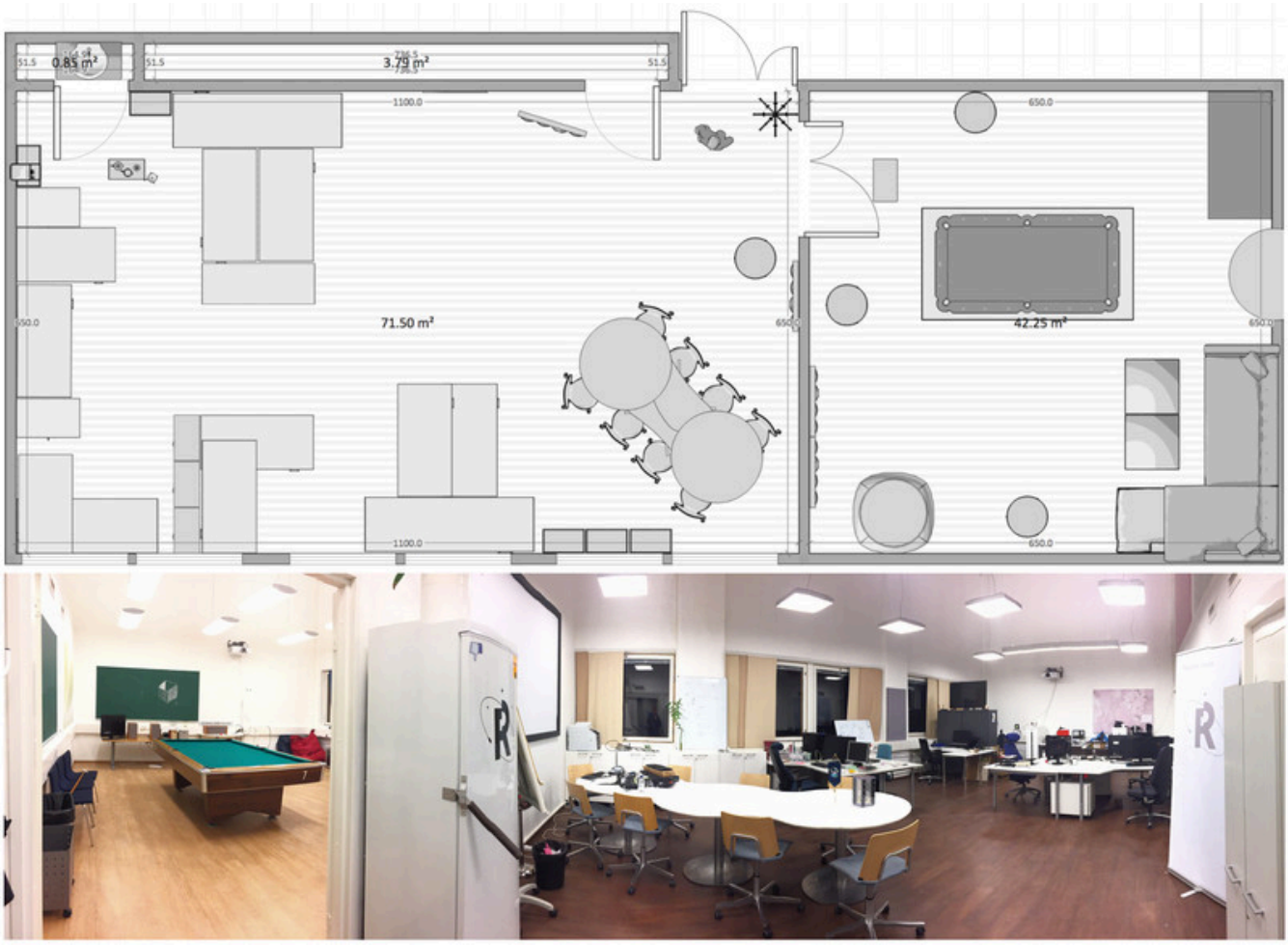
This means the date just **before** the pool table came in.

As part of the work happened in Aalto's labs and other premises **in close proximity** to the office, they are included in this study – that excludes Reaktor's main office, for example.



The *current environment* refers to the company's setting **right now**:

Again, Aalto's labs and other available premises **in close proximity** to the office do count in – soon-to-be ready clean room can be included in your answers.



2 Section 2 | This section measures the characteristics of the previous working environment (September 2016).

Please try to answer as honestly as you can!

Did the previous working environment support different kind of working styles? *

(For example: quiet work, team work and online meetings)

1 2 3 4 5 6 7

Did not support at all — Supported very well

Did the previous working space have the right tools for you? *

(In other words, were you able to achieve your working goals easily? Tools can be physical, digital and something in between)

1 2 3 4 5 6 7

I couldn't achieve my working goals with the tools available

I achieved my working goals very well with the existing tools

Did the previous working environment support immediate communication? *

(Examples: easy to start discussion with anyone, no need for postponing questions & replies)

1 2 3 4 5 6 7

Did not support at all

Strongly supported

On your opinion, was the previous working space flexible enough / easily changed? *

(In other words, was it easy to modify the space according to variable needs?)

1 2 3 4 5 6 7

The space felt permanent

The space felt very easily adjustable

Did the previous working environment encourage for immediate action? *

(In contrast to postponing tasks due practical limitations, for example)

1 2 3 4 5 6 7

It didn't encourage at all

It strongly encouraged

Did you feel that you could avoid interaction with other people when you wanted to focus? *

(Still in the previous working space)

1 2 3 4 5 6 7

I couldn't avoid interaction

It was very easy to avoid interaction

Did the previous working environment support constant testing? *

(For example, was it easy to prototype ideas on daily basis)

1 2 3 4 5 6 7

I couldn't carry out any testing — It was very easy to test my ideas

How easy it was to maintain a required overall cleanliness of the previous workspace? *

(In this case *cleanliness* includes order of tools & materials and hygiene aspects, for example. *Required* refers to necessary (minimum) level, in order to achieve proper quality of work and overall pleasantness)

1 2 3 4 5 6 7

It was almost impossible maintain cleanliness — It was very easy to maintain cleanliness

Did the previous working environment encourage you to have fun during the work day? *

1 2 3 4 5 6 7

The environment didn't allow to have fun — The environment strongly encouraged to have fun

In the previous working environment, did you feel confident about the credibility of your work? *

(For example: The collaborating institutions, like ESA and Tekes would approve your operations and methods, and the final outcomes will be space-proof)

1 2 3 4 5 6 7

I didn't feel confident at all — I felt extremely confident

How hierarchical did the previous working environment feel like? *

(Example characteristics of hierarchical organisation: top-down management, threshold on communication, inequality)

1 2 3 4 5 6 7

Not hierarchical at all — Extremely hierarchical

Did the previous working environment feel inviting for staying after hours? *

(After hours = personal free time)

1 2 3 4 5 6 7

Not inviting at all — Strongly inviting

Did the previous working environment meet your personal needs? *

(For example: comfort, concentration, intimacy)

1 2 3 4 5 6 7

It didn't meet my needs — It strongly met my needs

Did you feel you have been involved in the previous working space implementation? *

(Working space implementation includes planning, realisation and improvements)

1 2 3 4 5 6 7

I wasn't involved at all — I was strongly involved

Did the previous working environment support RSL's business point-of-view? *

(For example: marketing, meetings & visitors and overall credibility)

1 2 3 4 5 6 7

Didn't support at all — Strongly supported

Was the visual look of the previous workspace in line with Reaktor Space Lab's way of working? *

1 2 3 4 5 6 7

It wasn't in line at all — It was strongly in line

19 Section 3 | This section measures the characteristics of the current working environment.

Does the working environment support different kind of working styles? *

(For example: quiet work, team work and online meetings)

1 2 3 4 5 6 7

Does not support at all — Supports very well

Does the working space have the right tools for you? *

(In other words, are you able to achieve your working goals easily? – Tools can be physical, digital and something in between)

1 2 3 4 5 6 7

I cannot achieve my working goals with the tools available — I am able to achieve my working goals very well with the existing tools

Does the working environment support immediate communication? *

(Examples: easy to start discussion with anyone, no need for postponing questions & replies)

1 2 3 4 5 6 7

Does not support at all — Strongly supports

On your opinion, is the working space flexible enough / easily changed? *

(In other words, is it easy to modify the space according to variable needs?)

1 2 3 4 5 6 7

The space feels permanent — The space feels very easily adjustable

Does the working environment encourage for immediate action? *

(In contrast to postponing tasks due practical limitations, for example)

1 2 3 4 5 6 7

It doesn't encourage at all — It strongly encourages

Do you feel that you can avoid interaction with other people when you want to focus? *

1 2 3 4 5 6 7

I cannot avoid interaction — It is very easy to avoid interaction

Does the working environment support constant testing? *

(For example, is it easy to prototype ideas on daily basis?)

1 2 3 4 5 6 7

I cannot carry out any testing — It is very easy to test my ideas

How easy it is to maintain a required overall cleanliness of the workspace? *

(In this case *cleanliness* includes order of tools & materials and hygiene aspects, for example. *Required* refers to necessary (minimum) level, in order to achieve proper quality of work and overall pleasantness)

1 2 3 4 5 6 7

It is almost impossible maintain cleanliness — It is very easy to maintain cleanliness

Does the working environment encourage you to have fun during the work day? *

1 2 3 4 5 6 7

The environment does not allow to have fun

The environment strongly encourages to have fun

Do you feel confident about the credibility of your work? *

(For example: The collaborating institutions, like ESA and Tekes approve your operations and methods, and the final outcomes will be space-proof)

1 2 3 4 5 6 7

I don't feel confident at all

I feel extremely confident

How hierarchical does the working environment feel like? *

(Example characteristics of hierarchical organisation: top-down management, threshold on communication, inequality)

1 2 3 4 5 6 7

Not hierarchical at all

Extremely hierarchical

Does the working environment feel inviting for staying after hours? *

(After hours = personal free time)

1 2 3 4 5 6 7

Not inviting at all

Strongly inviting

Does the working environment meet your personal needs? *

(For example: comfort, concentration, intimacy)

1 2 3 4 5 6 7

It doesn't meet my needs

It strongly meets my needs

Do you feel that you have been involved in the current working space implementation? *

(Working space implementation includes planning, realisation and improvements)

1 2 3 4 5 6 7

I haven't involved at all — I've been strongly involved

Does the working environment support RSL's business point-of-view? *

(For example: marketing, meetings & visitors and overall credibility)

1 2 3 4 5 6 7

Does not support at all — Supports strongly

Is the visual look of the workspace in line with Reaktor Space Lab's way of working? *

1 2 3 4 5 6 7

It's not in line at all — It's strongly in line

36 Section 4 | Working methods

This section estimates working methods used in Reaktor Space Lab. The answer choices for the following five questions are a bit different from previous ones, however please try to estimate your answers as exact as you can.

a. During the past **5 working days**, how many times have you tested your ideas in practise? *

0 (I havent tested any ideas) 1-3 times 4-6 times 7-9 times 10-12 times

13-15 times >15 times

b. During the past **3 working days**, how many times have you been interrupted from your ongoing task by Slack messages? *

- 0 (haven't been interrupted at all)
- 1-3 times
- 4-6 times
- 7-9 times
- 10-12 times
- 13-15 times
- >15 times

c. On an **average working day** at RSL's office, how many times does your work get interrupted by other workers and/or their working methods? *

- 0 (haven't been interrupted at all)
- 1-2 times
- 3-4 times
- 5-6 times
- 7-8 times
- 9-10 times
- >10 times

d. On average, how big percentage of your working time does the **digital workspace** take?

(Digital workspace refers to any work done in digital / virtual world.)

Ooops! You must make a selection

e. On average, how many breaks* do you have during a working day? *

*In this case, a break refers to time spent on non-work-related things, for at least 5 minutes.

- 0 (no breaks at all)
- 1 break
- 2 breaks
- 3 breaks
- 4 breaks
- 5 breaks
- 6 breaks
- 7 breaks
- 8 breaks
- >8 breaks

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37 Section 5 | General statements

The last section consists of general statements. Please indicate how much you agree/disagree with them. Almost there!

The working environment supports easy documentation for external stakeholders. *

(For example: minimum documentation required by space agencies and authorities)

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

The working environment supports easy documentation for internal use. *

(For example: technical documentation & logs, knwoledge sharing and general information)

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

The working environment supports visualisation of your thoughts and ideas. *

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

The working environment supports adaptation of new technologies. *

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

I approve Otaniemi as the location for our company. *

(Example matters to consider: commuting, collaboration with companies and institutes, personal interests)

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

I feel passionate about working in Reaktor Space Lab's working environment. *

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

The purpose and goals of Reaktor Space Lab are clear to me. *

1 2 3 4 5 6 7

Disagree strongly (Neither agree nor disagree) Agree strongly

45 Finally, do you have any comments or concerns you would like to raise?

Feel free to express your opinions related to RSL's working environment, this survey or anything else! Remember that answers will be treated with the strictest confidence.

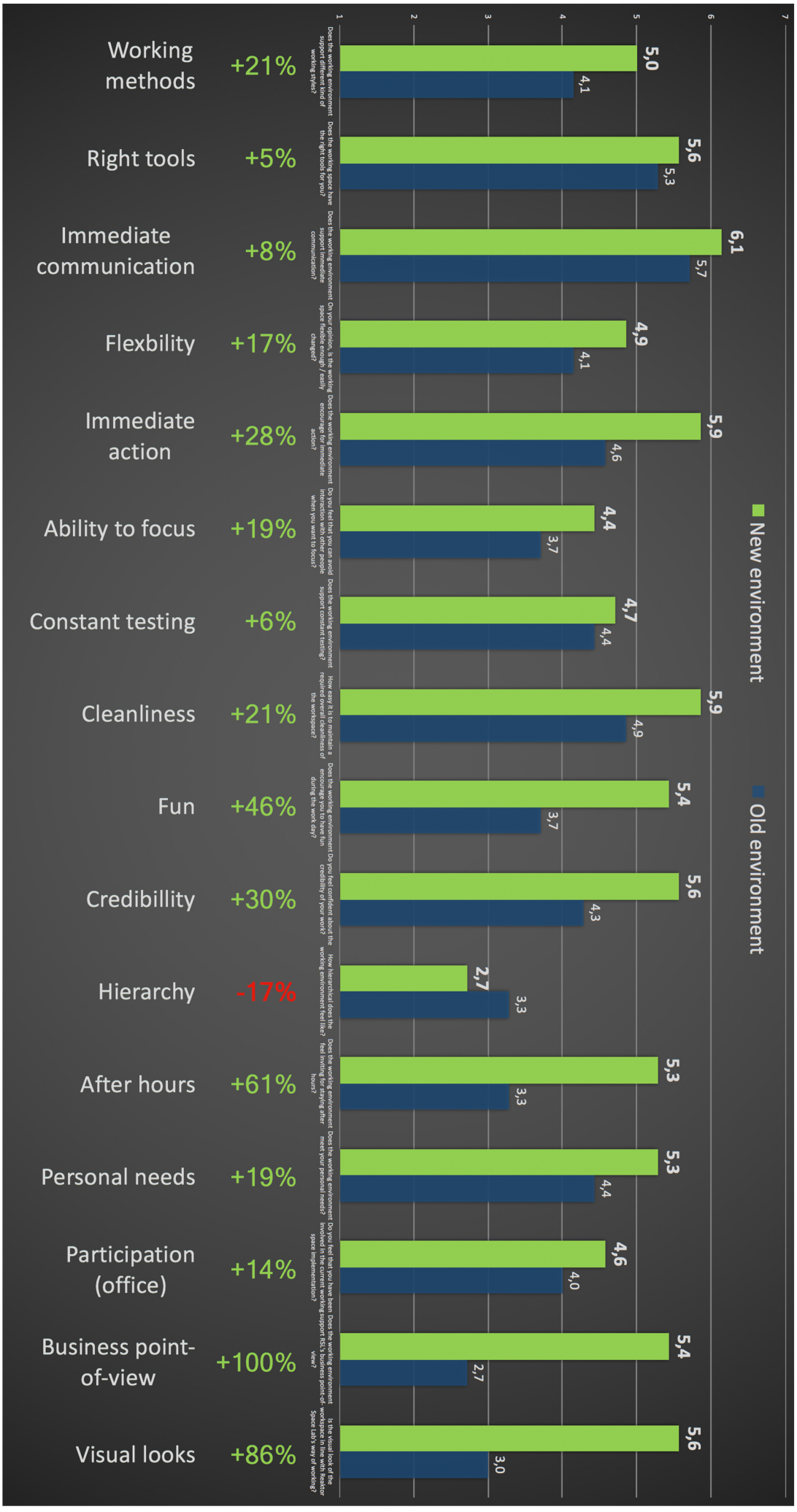
46 Thank you for participating this survey! *

For technical purposes and anonymity, please type a random word (or a combination of letters) that you can remember but which is not identifiable with you.

Also, please remember to press the "Submit"-button below! ↓

Submit

Appendix B: Survey Section 1 results



Appendix C: Survey Section 1 dispersion